NOTES

ON

POWER PLANT DESIGN

PREPARED
FOR THE USE OF STUDENTS IN THE
MECHANICAL ENGINEERING
DEPARTMENT
OF THE

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

EDWARD F. MILLER

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INTRODUCTION

An attempt has been made to assemble here, in condensed form, data which it is believed will be of assistance to one beginning on the laying out of a power plant.

Some of the material has been taken from articles which have appeared either in the Transactions of the American Society of Mechanical Engineers or in the engineering periodicals. Abstracts have also been made from Gebhardt's Steam Power Plant Engineering, from Koester's Steam Electric Power Plants, from Peabody and Miller's Steam Boilers, from Illustrations of Steam Engines, Steam Turbines, etc., from trade catalogues and from publications gotten out by manufacturers of the different pieces of apparatus which enter into the equipment of a power plant.

E. F. M.

TABLE OF CONTENTS

DISTRIBUTION OF HEAT

It is generally known that but a small proportion of the heat of the coal burned in a power plant goes into power.

In cases where there is a large demand for steam for heating during eight months of the year the exhaust steam from the engines or turbines used for power or lights may be saved by utilizing this steam in the heating system.

Under such conditions the cost of power for the period of heating is low and during this period the economy of the engine is of little moment provided there is never a surplus of exhaust steam. During the remaining four months when no heat is required, the economy of the engine is of importance.

Under all conditions the efficiency of the boiler affects the cost of operation.

The distribution of heat throughout a plant may be illustrated by the two cases worked out below.

Case I

Engine uses 30 lbs. steam, 100 lbs. gage per Brake Horse Power per hour; exhausting outboard.

Feed water enters boiler at 70°.

No heater installed.

	Per Cent by Weight	*B. T. U.*
Engine 30 (1187–38)	100	34,470
Feed Pump .6 (1187 –38)	2	689
Drips, radiation .45 (1187 –38)	1.5	517
		35,676
One horse power hour corresponds to		2,545

The thermal efficiency of the engine end $= \frac{2,545}{35,676} = .0713$

The boiler supplying steam we will assume to use a coal of 14,600 B. T. U. to the lb. and that the

	Per Cent
Per Cent of heat of coal utilized by boiler is	68
Per Cent lost by radiation, loss of coal through grate, etc. is	10
Per Cent of heat of coal carried off by flue gas is	22
	100

$$14,600 \times .68 = 9,928 \text{ B. T. U.}$$

Coal per Brake Horse Power Hour $= \frac{35,676}{9,928} = 3.594$ lbs.

The overall efficiency of the plant is $.0713 \times .68 = .0485$

which may be found by dividing $\frac{2,545}{3.594 \times 14,600} = .0485$

$$3.594 \times 14,600 = 52,470 \text{ B. T. U. per I. H. P. hour.}$$

Case II

Modern Turbine or Engine Plant using Superheated Steam at high pressure with 28″ vacuum in condenser. Economizer, Primary and Secondary heaters installed. Coal 14,600 B. T. U. per lb.

Combined Boiler and Economizer Efficiency = 76 per cent.

Boiler pressure 184 lbs. absolute, superheat 52° F. Back pressure 1 lb. absolute.

Feed water enters primary heater at 65°; leaves at 88°; enters secondary at 88°; leaves at 150°; enters economizer at 150°; leaves at 300°.

Engine or turbine requires 12.1 lbs. per I. H. P. hr. or 12.1 ÷.93 = 13 lbs. per brake horse power hour.

	Per Cent by Weight	*B.T.U.*
Engine or turbine 13 (1228.6 – 118)	100	14,438
Feed Pump	1.5	216
Circulating Pump for Condenser	3.0	432
Wet Pump	1.5	216
Dry Vacuum Pump	1.5	216
Drips, radiation, etc.	1.5	216
		15,734

$\frac{2,545}{15,734}$ = .1617 the engine efficiency assuming feed pump part of engine room outfit.

.1617 ×.76 = overall efficiency = .1229

The auxiliaries use 9% of engine steam, or .09 ×13 = 1.17 lbs. hr. per engine horse power. There is consequently 13 +1.17 = 14.17 lbs. passing through primary and secondary heater and through economizer per 13 lbs. supplied to engine.

(88 – 65) 14.17 = 326 B. T. U. recovered in Primary heater.

(150 – 88) 14.17 = 878 B. T. U. recovered in Secondary heater.

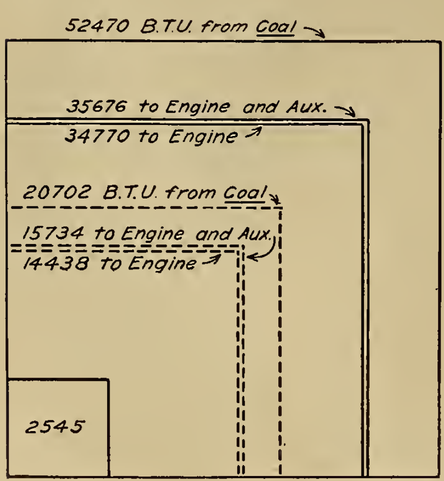
The total coal per engine horse power output hr. is

$$\frac{15,734}{14,600 \times .76} = 1.418 \text{ lbs.}$$

1.418 ×14,600 = 20,702 B. T. U. supplied by coal per engine H. P. output.

20,702 ×.1229 = 2,545 B. T. U. put into work or one horse power hour.

Had the primary and secondary heaters not been supplied there would have been required additional coal by an amount equal to $\frac{326 + 878}{14,600 \times .76}$ = .109 lbs. making the coal consumption per engine H. P. hr. = 1.528 lbs.



The results of these two calculations have been plotted in Fig. 1, the area of the small square in each case representing the heat units to be supplied for one horse power hour output. The full lines represent Case I and the dotted lines Case II.

The heat exhausted outboard per horse power hour is for Case I 35,676 – 2,545 = 33,131 B. T. U.

The heat exhausted to the condenser in Case II is 14,438 – 1,545 – 326 = 11,567 B. T. U. The 2,545 being the amount put into work and the 326 that transferred to the feed water in the primary heater.

Many plants like that cited in Case I with constantly growing demands for power, have overloaded engines, and boilers which cannot be run at increased pressures.

Often times if condensing water be available a low pressure turbine may be installed and the exhaust of the engine at from 1 to 5 lbs. gage pressure passed through the turbine and additional power amounting to from 50 to 80 per cent of the engine power obtained from the exhaust steam.

In general an engine designed to run non-condensing is not made sufficiently strong and the bearing surfaces are not large enough to stand the extra load brought to the parts when the engine is run condensing.

BOILERS

With few exceptions every large power plant where the units are steam driven, is equipped with some form of water tube boiler. This type is selected (1) because large powers can be obtained from single units, (2) because of the saving in floor space over that of any other type suitable for large power houses and (3) because high steam pressures in large units can be carried without any appreciable thickening of the metal through which the heat of the fire is transmitted.

A plant which is to be kept in continuous operation should have a sufficient number of units so that with one laid off for repairs the other units are able to carry the entire load.

Hand fired boilers working with natural draft can be run 33 per cent above their rating, without difficulty, provided the draft at the smoke outlet at normal rating is at least .5″ of water.

Stoker fired boilers working either with forced draft, induced draft or with both forced and induced draft may be run at times of peak load at 300 per cent of their rating. In recent years the boilers in nearly all of the power stations have been planned to develop from 150 to 200 per cent of their rating during ordinary running, and even higher than the figures given in times of emergency.

But little loss in thermal efficiency, results from forcing a boiler to 150 per cent of its rating.

When boilers are supplied with attached superheaters it is not advisable to have any possibility of a large amount of saturated steam being drawn from the drums of the boiler as such a procedure would result in the burning out of the superheater.

Boilers rated 400 to 600 H. P. cost per H. P., erected on foundations provided by the purchaser, from \$16.50 to \$17.50; with attached superheater, the price increases from \$1.00 to \$1.50 per H. P.

If the demand on a boiler plant amounted to 3600 H. P. and 2000 H. P. were installed, the boilers running 180 per cent of their rating, the reduction in first cost would amount to (\$16.50 + \$1.50) ×1600 = \$28,800. Taking interest, taxes, insurance, repairs and depreciation as 13 per cent, the saving on overhead charge would amount to .13 ×28,800 = \$3,744. Any slight loss in economy due to forcing the boilers would be more than offset by the reduced overhead on the building due to the smaller boiler room required.

Water tube boilers are given a nominal rating on a basis of 10 sq. ft. of heating surface per boiler horse power.

Tables giving some general dimensions of the Stirling, Heine and Babcock and Wilcox boilers follow.

These may be useful in getting general overall dimensions, weights, etc. It is evident that any of these boilers may be modified within certain limits.

As an illustration suppose it is found advisable to put in a B. & W. boiler 27 sections wide, 14 tubes high, tubes 18 ft. long. What would be the increase in width and in height over a boiler 21 wide and 9 high.

The width increases approximately 7″ per section and the height approximately 6″ per tube, making the width and height of the boiler 19′ – 6″ and 18′ – 3″ respectively.

With 4″ tubes the heating surface added per tube is

$$\frac{18' \times 4 \times 3.1416}{12} = 18.85 \text{ sq. ft.}$$

The 30 tubes add 566 sq. ft. or 57 H. P., making the rating 57 + 396 = 453 H. P.

It must be remembered that adding heating surface does not necessarily increase the power of a boiler; the grate surface must be increased in the proper proportion at the same time. Roughly a sq. ft. of grate is to be added for two 18 ft. tubes.

HEINE WATER TUBE BOILER

This boiler requires a space at the back as it is cleaned from the ends. Any number of boilers of this type can be set side by side.

The space in front of the boiler should be sufficient to allow of the renewal of a tube.

The length of setting from fire front to rear of brickwork is always 1 foot 4 inches longer than the length of the tubes, for instance, the setting of a 90 horse-power boiler is 17 feet 4 inches long and a 101 horse-power boiler is 19 feet 4 inches long. The shell with manhead extends about 15 inches beyond rear of setting, so that if possible a 4-foot space should be allowed behind the setting for access to same. In special cases the manhole is placed in the front head, or an opening may be made in the building wall opposite manhole, in which case 2 feet behind setting will be sufficient, The width of setting may be determined by adding the thickness of brick walls to the width of furnace. Thus, three 101 horse-power boilers in a battery, with 19 inches side and 28 inches division walls, will be 19″ + 53″ + 28″ + 53″ + 28″ + 53″ + 19″ = 21′ 1″. Existing walls may be utilized where space is limited, and the outside walls here reduced to a furnace lining 9 or 10 inches thick.

The grate-surface given for bituminous coal is such that the rating may be easily developed with a ½-inch draught at the smoke outlet. The grate area given for anthracite pea coal is that necessary in order to develop the rating of the boiler with ½-inch draught at the smoke outlet. For convenience of handling it is advisable to limit the grate length for anthracite coal to 7 feet 6 inches. Where this does not give area enough for the desired maximum capacity it is necessary to increase the draught. Standard grate lengths are 6 feet 6 inches, 7 feet and 7 feet 6 inches.

Safety-valves are provided as required to meet local inspection laws.

Heine Water-Tube Boilers

Horse-power	Square Feet Heating surface	Tubes 3½" Diameter No.	Tubes 3½" Diameter Length	Shells No.	Shells Diam.	Shells Length		Steam Outlet Diam.	Height of Flange Above Floor Level		Height of Center Line Above Floor Level Special		Diam. Feed-pipe
				1	Ins.	Ft.	Ins.	Ins.	Ft.	Ins.	Ft.	Ins.	Ins.
90	903	53	16	for	36	19	4½	4	11	7½	9	9½	1½
101	1010	53	18	all	36	21	4½	4	11	7½	9	9½	1½
113	1130	68	16	Horse	36	19	4½	4	12	2½	10	4½	1½
126	1263	68	18	Power	36	21	4½	4	12	2½	10	4½	1½
127	1273	77	16		36	19	4½	5	12	2½	10	4½	1½
143	1424	77	18		36	21	4½	5	12	2½	10	4½	1½
153	1533	94	16		36	19	4½	5	12	9½	10	11½	1½
171	1714	94	18		36	21	4½	5	12	9½	10	11½	1½
142	1420	86	16		42	19	6½	5	12	8½	10	10	1½
158	1588	86	18		42	21	6½	5	12	8½	10	10	1½
170	1708	105	16		42	19	6½	5	13	3½	11	5	1½
191	1911	105	18		42	21	6½	5	13	3½	11	5	1½
156	1564	95	16		42	19	6½	5	12	8½	10	10	1½
175	1749	95	18		42	21	6½	5	12	8½	10	10	1½
188	1883	116	16		42	19	6½	5	13	3½	11	5	1½
210	2106	116	18		42	21	6½	5	13	3½	11	5	1½
171	1716	104	16		48	19	9¼	6	13	2½	11	9½	2
192	1920	104	18		48	21	9¼	6	13	2½	11	9½	2
206	2061	127	16		48	19	9¼	6	14	2½	12	7½	2
230	2306	127	18		48	21	9¼	6	14	2½	12	7½	2
224	2244	138	16		48	19	9¼	6	14	2½	12	7½	2
250	2508	138	18		48	21	9¼	6	14	2½	12	7½	2
262	2621	163	16		48	19	9¼	6	14	9½	13	2½	2
293	2931	163	18		48	21	9¼	6	14	9½	13	2½	2
241	2417	149	16		48	19	9¼	6	14	6	12	10	2
270	2702	149	18		48	21	9¼	6	14	6	12	10	2
282	2826	176	16		48	19	9¼	6	15	1	13	5	2
316	3160	176	18		48	21	9¼	6	15	1	13	5	2
258	2586	160	16		48	19	9½	8	14	6½	12	10½	2
289	2892	160	18		48	21	9½	8	14	6½	12	10½	2
302	3024	189	16		48	19	9½	8	15	1½	13	5½	2
338	3383	189	18		48	21	9½	8	15	1½	13	5½	2

Blowoff-Cocks, 1½" Diam.	Furnace Width		Grates: Bituminous Coal Length		Area	Grates: Anthracite Pea Coal Length		Area	Space Occupied: Standard Setting Height over Safety-Valve		Standard Setting Height over Breeching		Special Settng Height over Shell at Front		Low Ceilings Height over Breeching	
No.	Ft.	Ins.	Ft.	Ins.	Sq. Ft.	Ft.	Ins.	Sq. Ft.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.
2	4	5	4	6	20.3	4	7½	20.4	13	4½	12	8	10	10	11	2
2	4	5	5	0	22.5	5	2½	23.0								
2	4	5	5	0	22.5	5	10	25.7	13	11½	13	4	11	5	11	11
2	4	5	5	6	24.7	6	5½	28.6								
2	5	0	5	0	25.4	5	9	28.8	13	11½	13	4	11	5	11	11
2	5	0	5	6	27.9	6	6	32.5								
2	5	0	6	0	30.4	6	11	34.7	14	6½	13	11	12	0	12	7
2	5	0	6	6	32.9	7	9	38.8								
2	5	7	5	0	28.4	5	9	32.2	14	7½	13	9	11	10½	12	6
2	5	7	5	6	31.2	6	5	35.9								
2	5	7	6	0	34.0	6	11	38.6	15	2½	14	4	12	5½	13	2
2	5	7	6	6	36.8	7	9	43.4								
2	6	2	5	0	31.4	5	9	35.4	14	7½	13	9	11	10½	12	7
2	6	2	5	6	34.4	6	6	39.9								
2	6	2	6	0	37.5	6	11	42.7	15	2½	14	4	12	5½	13	2
2	6	2	6	6	40.6	7	9	47.7								
2	6	9	5	0	34.3	5	9	38.8	15	3	14	7	12	11	13	9
2	6	9	5	6	37.7	6	6	43.6								
2	6	9	6	0	41.1	6	11	46.8	16	3½	15	3	13	9	14	11
2	6	9	6	6	44.5	7	9	52.2								
2	7	4	5	0	44.6	6	11	50.9	16	3½	15	3	13	9	15	0
2	7	4	5	6	48.4	7	9	56.8								
2	7	4	6	6	48.4	8	1	59.5	16	10½	15	10	14	4	15	7
2	7	4	6	0	52.0											
3	7	11	6	6	48.2	6	11	54.7	17	4½	15	10	14	0	15	6
3	7	11	6	0	52.2	7	9	61.3								
3	7	11	6	6	52.2	8	1	64.0	17	11½	16	6	14	7	16	2
3	7	11	7	0	56.1											
3	8	6	6	6	51.7	6	11	58.6	17	5	15	10	14	0½	15	6
3	8	6	6	0	56.0	7	9	65.6								
3	8	6	6	6	56.0	8	1	68.6	18	0	16	6	14	7½	16	2
3	8	6	7	0	60.2											

Heine Water-Tube Boilers

	Horse-power	Square Feet. Heating surface	Tubes 3½" Diameter		Shells				Steam Outlet				
			No.	Length	No.	Diam.	Length		Diam.	Height of Flange Above Floor Level		Height of Center Line Above Floor Level Special	
						Ins.	Ft.	Ins.	Ins.	Ft.	Ins.	Ft.	Ins.
Double-	280	2808	171	16	2	36	19	4½	8	14	1	11	11½
shell	314	3140	171	18	for	36	21	4½	for	14	1	11	11½
boilers	328	3280	202	16	all	36	19	4½	all	14	8	12	6½
	367	3669	202	18	horse-	36	21	4½	horse-	14	8	12	6½
	297	2978	182	16	powers	36	19	4½	powers	14	1	11	11½
	333	3330	182	18		36	21	4½		14	1	11	11½
	348	3479	215	16		36	19	4½		14	8	12	6½
	389	3892	215	18		36	21	4½		14	8	12	6½
	254	2546	154	16		36	19	4½		12	10½	10	10½
	285	2848	154	18		36	21	4½		12	10½	10	10½
Two	284	2840	172	16		42	19	6½		13	4½	11	4
sections	317	3176	172	18		42	21	6½		13	4½	11	4
over	341	3416	210	16		42	19	6½		13	11½	11	11
one	382	3822	210	18		42	21	6½		13	11½	11	11
furnace.	312	3128	190	16		42	19	6½		13	4½	11	4
	350	3498	190	18		42	21	6½		13	4½	11	4
	576	3766	232	16		42	19	6½		13	11½	11	11
	421	4212	232	18		42	21	6½		13	11½	11	11
	440	4400	274	16		42	19	6½		14	6½	12	6
	492	4924	274	18		42	21	6½		14	6½	12	6
	343	3432	208	16		48	19	9¼		13	10½	11	9½
	384	3840	208	18		48	21	9¼		13	10½	11	9½
	412	4122	254	16		48	19	9¼		14	10½	12	7½
	461	4612	254	18		48	21	9¼		14	10½	12	7½
	482	4822	300	16		48	19	9¼		15	5½	13	2½
	539	5396	300	18		48	21	9¼		15	5½	13	2½
	448	4488	276	16		48	19	9¼		14	10½	12	7½
	501	5016	276	18		48	21	9¼		14	10½	12	7½
	524	5242	326	16		48	19	9¼		15	5½	13	2½
	586	5862	326	18		48	21	9¼		15	5½	13	2½

Diam. Feed-pipe	Blowoff Cocks, 1½" Diam.	Furnace Width		Grates						Space Occupied							
				Bituminous Coal			Anthracite Pea Coal			Standard Setting				Special Setting, Height over Shell at Front		Low Ceilings Height over Breeching	
				Length		Area	Length		Area	Height over Safety-Valve		Height over Breeching					
Ins.	No.	Ft.	Ins.	Ft.	Ins.	Sq. Ft.	Ft.	Ins.	Sq. Ft.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.
2½	4	9	1	6	0	55.2	7	0	63.6	15	4½	15	6	13	1	14	5
2½	for	9	1	6	6	59.8	7	10	71.3								
2½	all	9	1	6	0	59.8	8	3	74.5	15	11½	16	1	13	8	15	0
2½	horse-	9	1	7	6	64.4											
2½	powers	9	8	6	0	58.8	7	0	67.5	15	4½	15	6	13	1	14	6
2½		9	8	6	6	63.6	7	10	75.6								
2½		9	8	6	0	63.6	8	2	79.0	15	11½	16	1	13	8	15	1
2½		9	8	7	6	68.5											
2-1½		10	7	5	0	53.7	5	6	57.7	13	11½	13	10	11	11	12	11
2-1½		10	7	5	6	59.0	6	2	64.8								
2-1½		11	9	5	0	59.7	5	6	64.5	14	7½	14	3	12	4½	13	3
2-1½		11	9	5	6	65.6	6	2	72.0								
2-1½		11	9	6	0	71.5	6	7	77.3	15	2½	14	10	12	11½	13	10
2-1½		11	9	6	6	77.3	7	5	86.7								
2-1½		12	11	5	0	65.7	5	6	70.8	14	7½	14	3	12	4½	13	9
2-1½		12	11	5	6	72.1	6	2	79.5								
2-1½		12	11	6	0	78.6	6	7	85.4	15	2½	14	10	12	11½	14	6
2-1½		12	11	6	6	85.0	7	5	95.7								
2-1½		12	11	6	0	85.0	7	9	100.0	15	9½	15	5	13	6½	15	1
2-1½		12	11	7	9	91.5											
2-2		14	1	5	0	71.5	5	7	78.0	15	3	14	7	12	11	13	9
2-2		14	1	5	6	78.5	6	2	87.2								
2-2		14	1	6	0	85.3	6	8	93.6	16	3½	15	9	13	9	14	11
2-2		14	1	6	6	92.8	7	5	104.8								
2-2		14	1	6	0	92.3	7	9	109.5	16	10½	16	4	14	4	15	6
2-2		14	1	7	6	99.7											
2-2		15	3	6	0	92.7	6	8	101.8	16	3½	15	9	13	9	15	0
2-2		15	3	6	6	100.3	7	6	114.0								
2-2		15	3	6	0	100.3	7	10	119.1	16	10½	16	4	14	4	15	7
2-2		15	3	7	6	108.0											

STIRLING BOILERS

These boilers clean from the side, and only two can be set together without a space between. If necessary the boiler may be set without a space at the back, but it is advisable to have at least 3 feet back of the rear wall.

These boilers are also built with attached superheaters. The superheater is placed at different parts of the setting, according to the number of degrees of superheating desired.

The following table gives dimensions of this boiler for different boiler horse-powers.

If the boiler is equipped with a superheater, deduct 10 per cent from the rated horse-power. If, however, the superheater is flooded the capacity of the boiler is increased approximately 7 per cent above the ratings given.

Horse-Power of Stirling Boilers

Width of Setting Single ft.	in.	Battery* feet	CLASS B-low 11′ 11″ 14′ 0″	P 15′ 4½″ 18′ 7″	E 15′ 3″ 16′ 3″	B 15′ 8″ 14′ 0″	A Height 18′ 9″ Depth 16′ 0″	Q 18′ 10″ 18′ 9″	F 20′ 7″ 16′ 9″	R 20′ 8″ 18′ 2″	K 21′ 10″ 17′ 7″	L 22′ 4″ 18′ 3″	N 24′ 6″ 18′ 10″
5	6	10	50	...	...	50	...	...	...	...	...	...	...
6	0	11	55	...	75	60	...	...	...	...	...	...	...
6	6	12	65	...	90	70	...	...	...	...	...	...	...
7	0	13	75	115	100	80	115	145	140	145	150	165	175
7	6	14	85	130	115	90	130	165	155	160	170	185	195
8	0	15	95	145	125	100	145	180	175	180	185	205	220
8	6	16	105	160	140	110	160	200	190	200	205	230	240
9	0	17	115	175	150	120	175	215	205	215	225	250	260
9	6	18	125	190	165	130	190	235	225	235	245	270	285
10	0	19	135	205	175	140	205	255	240	250	260	290	305
10	6	20	140	220	190	150	215	270	260	270	280	310	330
11	0	21	150	230	200	160	230	290	275	285	300	330	350
11	6	22	160	245	215	170	245	310	295	305	315	350	370
12	0	23	170	260	225	180	260	325	310	325	335	370	395
12	6	24	180	275	240	190	275	345	330	340	355	395	415
13	0	25	190	290	250	200	290	360	345	360	375	415	435
13	6	26	200	305	265	210	305	380	360	375	390	435	460
14	0	27	210	320	275	220	320	400	380	395	410	455	480
14	6	28	220	335	290	230	335	415	395	410	430	475	505
15	0	29	230	350	300	240	350	435	415	430	450	495	525
15	6	30	240	365	315	250	360	450	430	450	465	515	545
16	0	31	250	375	330	260	375	470	450	465	485	540	570
16	6	32	260	390	340	270	390	490	465	485	505	560	590
17	0	33	265	405	355	280	405	505	485	505	520	580	610
17	6	34	275	420	365	290	420	525	500	520	540	600	635
18	0	35	285	435	380	300	435	545	515	540	560	620	655

* The horse-power is double for battery width shown. Single boilers require an alley on one side; battery boilers require an alley on both sides.

BABCOCK AND WILCOX BOILERS

These boilers clean from the side. There must be a space of at least 5 feet between each set of two.

The tables give space taken up by boilers with vertical headers. For inclined headers, any number of tubes high, add 3 feet 8 inches to the length given. A double-deck boiler is 10 inches higher than a single-deck boiler of same number of tubes high.

Space must be left in front of the boiler to enable the lowest tube to be replaced.

Babcock and Wilcox Vertical Header Boilers.—Single Deck

	Horse-power at 10 Square Feet	Heating surface, Square Feet	Sections Wide	Sections High	Sections Long	Drums No.	Drums Dia.	Drums Length		Nozzle Dia.	Nozzle Flange	Steam Opening Dia.	Steam Opening Flange
					Ft.		Ins.	Ft.	Ins.	Ins.	Ins.	Ins.	Ins.
One	101.8	1018	6	9	16	1	36	18	7¼	5	11	5	11
Boiler	114.3	1143	6	9	18	1	36	20	2	5	11	5	11
in	117.5	1175	7	9	16	1	36	18	7¼	5	11	5	11
One	132.0	1320	7	9	18	1	36	20	2	5	11	5	11
Battery.	134.5	1345	8	9	16	1	42	18	7¼	5	11	5	11
	151.0	1510	8	9	18	1	42	20	2	5	11	5	11
	150.2	1502	9	9	16	1	42	18	7¼	5	11	5	11
	168.7	1687	9	9	18	1	42	20	2	6	12½	6	12½
	203.6	2036	12	9	16	2	36	18	7¼	8	15	8	15
	228.7	2287	12	9	18	2	36	20	2	5	11	8	15
	235.1	2351	14	9	16	2	36	18	7¼	5	11	8	15
	264.0	2640	14	9	18	2	36	20	2	5	11	8	15
	269.0	2690	16	9	16	2	42	18	7¼	5	11	8	15
	302.1	3021	16	9	18	2	42	20	2	5	11	8	15
	300.5	3005	18	9	16	2	42	18	7¼	5	11	8	15
	337.5	3375	18	9	18	2	42	20	2	5	11	8	15
	352.7	3527	21	9	16	3	36	18	7¼	5	11	10	17½
	396.0	3960	21	9	18	3	36	20	2	5	11	10	17½

Safety Valve No.	Safety Valve Dia.	Feed	Mud-drums Hand Hole	Mud-drums Blow-off No.	Mud-drums Blow-off Dia.	Height from Floor to top of Steam Outlet		Front of Boiler to Center of Steam Outlet		Grates Length		Grates Width		Grates Area
	Ins.	Ins.	No.			Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	
1	3½	1½	1	1	2	14	8	3	2	6	0	3	10	23.00
1	3½	1½	1	1	2	14	8	or		7	0	3	10	26.81
1	3½	1½	1	1	2½	14	8	8	2	6	0	4	5	26.50
1	4	1½	1	1	2½	14	8			7	0	4	5	30.94
1	4	1½	2	1	2½	15	2			6	0	5	0	30.00
1	4	1½	2	1	2½	15	2			7	0	5	0	35.00
1	4	1½	2	1	1½	15	2			6	0	5	7	33.50
1	4½	1½	2	1	2½	15	2			7	0	5	7	39.06
2	3½	2	3	2	2½	15	8			6	0	7	4	44.00
2	3½	2	3	2	2½	15	8			7	0	7	4	51.31
2	4	2	4	2	2½	15	8			6	0	8	6	51.00
2	4	2	4	2	2½	15	8			7	0	8	6	59.50
2	4	2	4	2	2½	16	2			6	0	9	8	58.00
2	4	2	4	2	2½	16	2			7	0	9	8	67.66
2	4	2	4	2	2½	16	2			6	0	10	10	65.00
2	4½	2	4	2	2½	16	4½			7	0	10	10	75.81
3	4	2½	4	3	2½	15	9			6	0	12	7	75.50
3	4	2½	4	3	2½	15	9			7	0	12	7	88.06

Space Occupied Length		Space Occupied Width		Approx. Weight of Water	Approx. Suspended Weight Including Water	Approx. Total Weight of Setting	Approx. Shipping Weight	Red Brick	Fire-brick
Ft.	Ins.	Ft.	Ins.					No.	No.
17	9½	6	8	9,200	29,300	120,000	26,000	14,200	3250
19	9	6	8	10,170	31,300	130,600	27,500	15,600	3550
17	9½	7	3	10,020	32,100	126,000	28,600	14,500	3450
19	9	7	3	11,080	34,300	137,800	30,300	16,000	3700
17	9½	7	10	12,330	38,600	135,300	32,700	15,100	3700
19	9	7	10	13,720	41,300	147,000	34,800	16,600	3950
17	9½	8	5	13,220	41,300	142,800	36,400	15,300	3950
19	9	8	5	14,670	44,200	155,100	38,300	16,700	4100
17	9½	10	2	18,400	59,200	151,500	47,400	15,800	4000
19	9	10	2	20,340	63,200	163,600	50,300	17,400	4550
17	9½	11	4	20,040	64,900	162,500	53,600	16,400	4400
19	9	11	4	22,160	69,300	175,100	56,000	17,900	4700
17	9½	12	6	24,600	78,000	178,900	62,200	17,200	4700
19	9	12	6	27,440	83,400	191,900	65,900	18,900	5200
17	9½	13	8	26,440	83,600	190,700	68,400	17,800	4950
19	9	13	8	29,340	89,300	204,900	72,500	19,500	5300
17	9½	15	5	30,060	108,700	209,800	79,100	18,100	5200
19	9	15	5	33,240	116,200	224,100	83,900	20,000	5400

Babcock and Wilcox Vertical Header Boilers.—Single Deck

	Horse-power at 10 Sq. Feet	Heating-surface Sq. Ft.	Width of Settings Ft.	Ins.	Shipping Weight	Red Brick Number	Fire Brick Number
Two	203.6	2036	11	11	52,000	20,300	6,500
	228.6	2286	11	11	55,000	22,000	7,100
Boilers							
	235.0	2350	13	1	57,200	20,900	6,900
in One	264.0	2640	13	1	60,600	23,000	7,400
Battery.	269.0	2690	14	3	65,400	21,900	7,400
	302.0	3020	14	3	69,600	24,000	7,900
	300.4	3004	15	5	72,800	22,200	7,700
	337.4	3374	15	5	76,600	24,300	8,200
	407.2	4072	19	6	94,800	26,800	8,000
	457.4	4574	19	6	100,600	29,400	9,100
	470.2	4702	21	10	107,200	27,900	8,800
	528.0	5280	21	10	112,000	30,500	9,400
	538.0	5380	24	2	124,400	30,200	9,400
	604.2	6042	24	2	131,800	32,400	10,400
	601.0	6010	26	6	136,800	31,600	9,900
	675.0	6750	26	6	145,000	33,600	10,600
	705.4	7054	30	0	158,200	31,650	10,400
	792.0	7920	30	0	167,800	34,750	10,800

Both the B. & W. and the Stirling have cleaning doors for blowing soot from the tubes on the side, consequently only two boilers can be placed side by side without an aisle.

The height of the tubes above the grate can be made to suit the requirements of the engineer; a much greater height is used now than was the custom a few years ago.

In many boiler houses the boilers are located on the first floor above the basement which may be at ground level or below ground level.

The space below the boiler is used for collecting the ash, for the main steam line and feed pump lines, for conveying machinery, etc. The boilers are supported, in such cases, by steel beams running between the columns which must be spaced to suit the width of the boilers used.

The column spacing is often made unequal to allow for a 5 or 6 ft. aisle between batteries.

In some cases where small units are installed, the two boilers in any one battery are carried at the front end by steel beams, running from the face of a column at one side of the battery to a similar column at the other side. This method of supporting requires a rather heavy beam. More often there is a column in the center of the battery. In every case the columns must be protected by a sleeve so that should the brickwork of the boiler become burned through, there would be no possibility of the heat of the fire softening the column.

This sleeve is frequently made of thin iron encircling the column to a height of three or four feet above the tubes, the sleeve being open at the bottom and at the top to allow of a circulation of air between the sleeve and the column.

When boilers are carried by beams attached to the side of the columns there is an eccentric load brought to the end columns. These columns adjacent to the aisles between batteries must be diagonally braced above the boilers on account of this eccentric loading. The back ends of the boilers may be supported in the same way as the front ends or I beam uprights resting on steel floor beams, may serve to carry the cross beams from which the drums of the boiler are suspended.

When a boiler house is arranged with a double row of boilers, having a firing aisle in the centre the coal pocket is often suspended from the columns so as to utilize the space over the firing aisle.

Economizers if used, would then be located over the boilers at the back end; this plan utilizes space otherwise wasted but makes a boiler room which is dark. An arrangement found in some of the large plants in Chicago secures both a well lighted and a well ventilated boiler room.

The boilers at both front and back are supported by columns which are carried up to the roof. A coal pocket is hung between these columns over each row of boilers and the middle bay, which is the firing aisle, is open to the roof, which in this bay is of the monitor type.

FLUES FOR BOILERS

The area of the flue leading from a row of boilers to the stack should be as great as the area of the stack designed to carry the row. It is evident that a greater draft obtained from a high stack would diminish the cross sectional area required by a shorter stack giving less draft. The old rule which applied to hand fired boilers by which the flue area was made from 1/8 to 1/10 the grate area does not hold with stoker fired boilers under which coal is burned at three times the rate found common with hand fired boilers.

To illustrate the method of determining the size of the flue for a row of boilers let us assume that 5000 lbs. of coal are burned per hour under a battery of boilers. Chimney 150 feet high. Referring to the chart of chimney capacity in the section treating of chimneys, it is seen that a chimney 150 feet tall will take care of 176 lbs. of coal per hour per sq. ft. of chimney area according to Kent's values and 157 lbs. according to Christie's values.

It appears from these figures that a flue of from 28 to 32 sq. ft. area is required.

BOILERS USING FUEL OIL

In the middle western states and in the southwestern part of the country oil is in general use for steam generation.

On account of the sudden fluctuations in the price of oil here in the east very few concerns in this part of the country have used oil.

Contracts are now being made, however, for delivery of oil at a fixed price through a long period of years and there is every reason to believe that the use of oil in this part of the country will increase.

Texas oil has a heating value of approximately 18,500 B. T. U. per pound. It contains generally about 2 per cent of moisture although in some cases as much as 25 per cent has been found.

The gross efficiency of an oil fired boiler plant is with good management about 82 per cent; as 2 per cent of the steam made is used in heating the oil and in spraying it, a net efficiency of 80 per cent may be expected.

An efficiency of 75 per cent would be considered very good for a coal fired boiler, 70 being nearer that obtained in every day running in the best plants.

The price of oil varies either side of $1.00 per barrel of 42 gallons, 8 lbs. to the gallon.

A table giving the number of barrels of oil equivalent to a ton of coal burned with boiler efficiencies varying from 65 to 75 per cent will enable one to make a comparison of the cost of evaporation, using oil at so much a barrel as against coal of a certain price per ton.

Heat Value of Coal 14,600 per lb.

	Boiler Efficiency				
	.750	.725	.70	.675	.650
Equivalent Evaportation per lb. coal from and at 212° F. in lbs.	11.284	10.908	10.532	10.392	9.779
Barrels of oil 336 lbs. to barrel 18,500 B. T. U. per lb. burned with 80 per cent net efficiency equivalent to one ton of coal of 14,600 B. T. U. to lb.	5.543	4.257	4.110	3.964	3.817

Oil weighs 8 lbs. per gallon.
42 gallons per barrel.

The crude oil has to be stored in steel tanks, generally placed underground outside of the building. The oil in the tank must be heated by a steam coil in order to keep it sufficiently fluid to flow through the suction pipe of the oil pump supplying the burners with oil under 30 to 50 lbs. pressure. The exhaust of the oil pump is frequently used to still further heat the oil before it enters the burner.

The temperature of the oil should not be high enough to cause the gas to volatilize as this would cause the flame at the burner to be extinguished and might result in a flooding of the furnace and an explosion.

The advantages and the disadvantages of petroleum as a fuel compared with coal are given in "Steam" thirty-fifth edition, Babcock and Wilcox Co.'s catalogue, page 214, as follows:

The advantages of the use of oil fuel over coal may be summarized as follows:

1st. The cost of handling is much lower, the oil being fed by simple mechanical means, resulting in:

2nd. A general labor saving throughout the plant in the elimination of stokers, coal passers, ash handlers, etc.

3rd. For equal heat value, oil occupies very much less space than coal. This storage space may be at a distance from the boiler without detriment.

4th. Higher efficiencies and capacities are obtainable with oil than with coal. The combustion is more perfect as the excess air is reduced to a minimum; the furnace temperature may be kept practically constant as the furnace doors need not be opened for cleaning or working fires; smoke may be eliminated with the consequent increased cleanliness of the heating surfaces.

5th. The intensity of the fire can be almost instantaneously regulated to meet load fluctuations.

6th. Oil when stored does not lose in calorific value as does coal, nor are there any difficulties arising from disintegration, such as may be found when coal is stored.

7th. Cleanliness and freedom from dust and ashes in the boiler room with a consequent saving in wear and tear on machinery; little or no damage to surrounding property due to such dust.

The disdavantages of oil are:

1st. The necessity that the oil have a reasonably high flash point to minimize the danger of explosions.

2nd. City or Town ordinances may impose burdensome conditions relative to location and isolation of storage tanks, which in the case of a plant situated in a congested portion of the city, might make the use of this fuel prohibitive.

3rd. Unless the boilers and furnaces are especially adapted for the use of this fuel, the boiler upkeep cost will be higher than if coal were used. This objection can be entirely obviated, however, if the installation is entrusted to those who have had experience in the work, and the operation of a properly designed plant is placed in the hands of intelligent labor.

SIZE OF STACK REQUIRED FOR OIL BURNING BOILERS

The cross sectional area of stack for an oil burning boiler need be only 60 per cent of that required by the same plant burning coal. This may be shown by a simple calculation.

The composition of a semi-bituminous coal is approximately $C = .85$ $H = .06$ ash, sulphur moisture, etc. .09.

Fuel oil is made up of $C = .84$, $H = .12$, S. N. O. and moisture .06.

The air for coal $= 11.5 \times .85 + .06 \times 34.5 = 12.34$ lbs.; allowing 50 per cent dilution in order to get air to all parts of furnace gives 18.51 lbs.

For oil $11.5 \times .85 + .12 \times 34.5 = 13.86$; allowing 20 per cent for dilution gives 16.63 lbs.

As the heat utilized by the boiler from a pound of coal is about 10,000 B. T. U., while that taken up from a pound of oil is about 14,800 B. T. U., it is evident that 1.48 lbs. of coal would be required to furnish the heat absorbed from one pound of oil and consequently the weight of gases from the coal fired boiler would in comparison with the oil be as $1.48 \times 18.51 = 27.39$ is to 16.63, which means that the same stack will with oil fired boilers have 1.65 the capacity of coal fired boilers.

Many plants which are overloaded, which have insufficient chimney area and in which there is not room for the installation of mechanical stokers with forced or induced draft fans, have adopted oil burning.

ECONOMIZERS

Economizers are made up of cast iron tubes 4″ to 4½″ inside diameter and 9′ long. The tubes are turned at the end to a slight taper and are forced into top and bottom headers by hydraulic pressure. These headers are made to take different numbers of tubes, as is shown by the table of dimensions given on pages which follow. The lower headers project through the brick work housing and are joined together by a "bottom branch pipe" running lengthwise of the economizer. This "bottom branch pipe" has on one side, a series of flanges for making the connection with the bottom headers and on the opposite side, in line with each header, a hand hole through which the header may be cleaned. The feed water enters this "bottom branch pipe" at the end of the economizer nearer the chimney and leaves the economizer at the top, at the end nearer the boiler. The top headers are similarly connected. This pipe joining the top headers is placed above, instead of at the end of the header, and at the opposite side of the economizer. In some cases means are provided for washing out the bottom headers, by sending a stream of water from a hose down through the tubes at the back end of the bottom headers and letting it flow along the entire length of the bottom headers and out through the clean-out openings directly opposite the headers.

In setting up an economizer, room should be left opposite these clean-out openings so that a scraper can be put into each header to remove any scale which may lodge there, as the headers are sometimes cleaned out in this way instead of by washing out.

In order to repair a tube and replace it by a second tube without dismantling that section or that header, a slot is made in the upper end of the tube with a chisel so as to enable the tube to be sprung together. The tube is then withdrawn from the bottom header in the following manner:

A piece of iron shaped as shown by the accompanying sketch is pushed down inside the tube and moved to one side so as to engage the bottom end of the tube, this piece being held by a rod with thread and nut at the top. A second piece like a wedge, is held against the first piece by a second rod and prevents any side motion of the first piece. By screwing on the first nut the tube may now be withdrawn from the bottom header. The new tube is now inserted, driven into the bottom header, and a conical wedge used to make the joint between the tube and the top header. Sometimes a tube which has given trouble may be plugged and cut out of service.

As the tubes are withdrawn through the top of the economizer, or in case of serious mishap, the entire section is taken up through the top of the economizer,— there should be sufficient room left over the economizer to allow for this. The arrangement of the brickwork should be such as to enable a section to be withdrawn without making it necessary to take down a large amount of masonry.

The heating surface needed may be put either in one large economizer, through which all the gases from all of the boilers pass, or there may be a number of smaller economizers known as "unit economizers," one for each battery of boilers. With the first arrangement, any accident to the economizer which might put it out of service, would reduce the power of the boiler plant 10 or 15 per cent. The draft would be reduced to a considerable amount by this arrangement.

In the second arrangement, as only one unit would be cut out, in case of accident, the reduction in power of the boiler plant would be inappreciable.

The flue gas leaving the boiler should have a direct passage to the chimney around the economizer. Suitable dampers should be provided so that the gases may be sent either through the economizer or directly to the chimney. When the economizer is out of service both dampers at entrance and exit to the economizer should be closed.

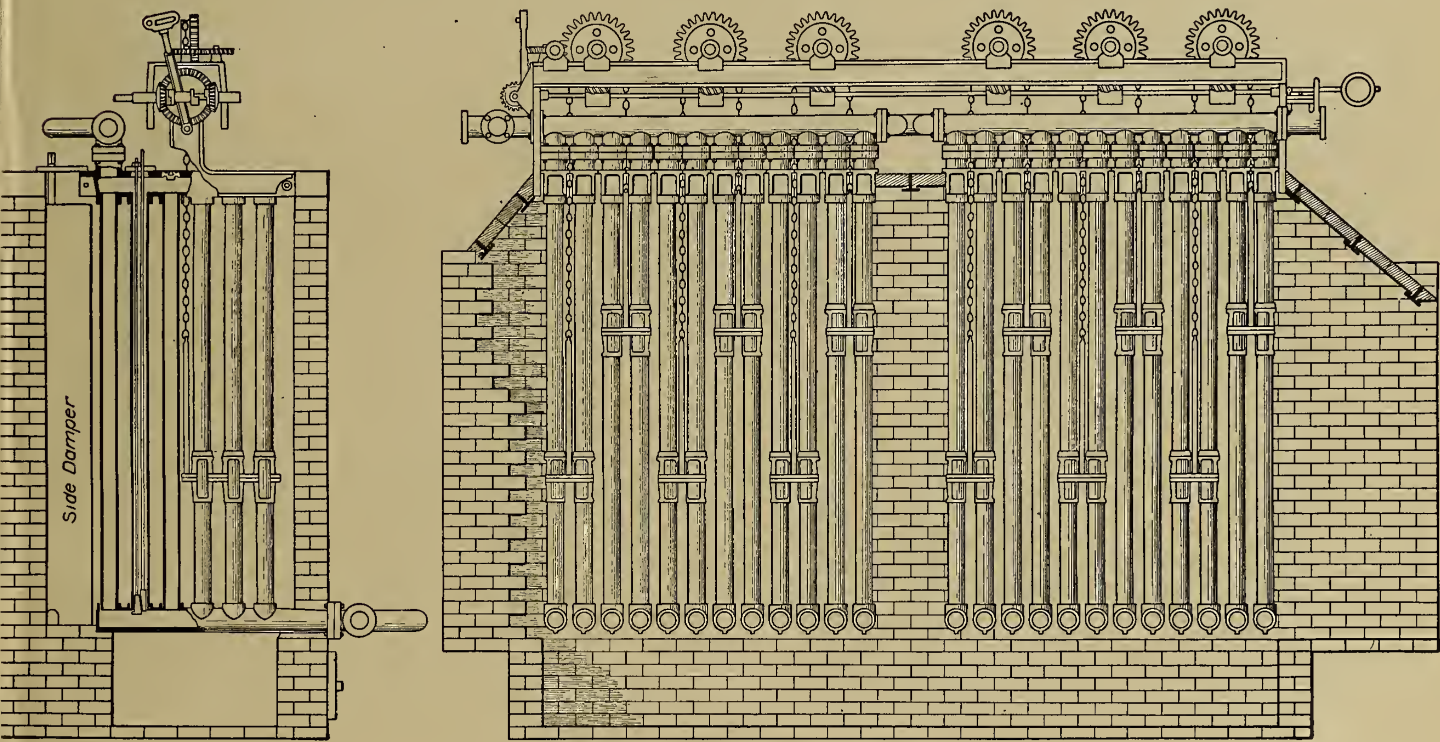
In general, an economizer will save from 8 to 15 per cent. In figuring whether the saving is going to pay for the interest on the first cost, and for the depreciation, the saving to be made in any particular case has to be taken into account. The life of an economizer is generally considered to be 20 years, and the cost set is generally taken as about $4.50 per boiler horse power or $10 to $12 per tube erected. This latter figure does not include an induced draft-outfit which if installed would add to the cost.

Reducing the temperature of the flue gas by passing it through the economizer reduces the draft practically in the proportion that the absolute temperature of the flue gas is reduced. The draft is still further reduced by the friction of the gas in passing through the economizer and in the many instances where the draft is poor, it would be unwise to install an economizer unless an induced draft fan were to be installed also. Usually on the side of the economizer there is a space about 12 inches wide left between the last tubes and the casing or brickwork, to allow of inspection. Sometimes there are two such passages, one either side of the economizer. These passages are closed by side dampers when the economizer is in use.

Provision should be made for removing the soot from the bottom of the economizer. To remove the soot which collects on the tubes, scrapers are provided, these scrapers being in the form of loose collars which are alternately raised and lowered by chains operated from a shaft running along the top of the economizer. If the economizer is only eight tubes wide, one shaft will serve, but if the economizer is ten or twelve tubes wide there should be two sets of shafts. In place of the brickwork walls a sectional covering of steel bolted together through angle irons may be used. This covering is insulated by building it up of two steel plates with 2″ of magnesia or asbestos as an insulating material between.

The economizers must each be provided with a relief valve of sufficient size, and with a blow-off valve. Various arrangements of economizers as applied to different types of boilers, and the various arrangements of the direct flues may best be seen by studying some of the cuts of power stations or by referring to some of the cuts shown on later pages.

The economizer is always connected on the feed line in such a way that the feed may be by-passed around the economizer, and when the economizer becomes steam bound it should be cut out and allowed to cool until the steam has condensed.



The rise of temperature of the feed-water in an economizer may be calculated as follows:
T_h = temperature of flue gas entering economizer.
T_c = temperature of flue gas leaving economizer.
t_h = temperature of feed water leaving economizer.

t_c = temperature of feed water entering economizer.
.24 = specific heat of flue gas.
30 = number of pounds of water fed per boiler H. P.
24 = pounds of flue gas per pound of coal.
9 = probable evaporation of water per pound of coal.

$$(T_h - T_c) \times 24 \times \frac{30}{9} \times .24 = 30\ (t_h - t_c)$$

$$T_c = T_h - 1.562\ (t_h - t_c)$$

For different evaporations or for different weights of flue gas per pound of coal the value to replace 1.562 may be easily figured.

S = square feet of heating surface in the economizer per boiler H. P. or per 30 lbs. of feed water fed per hour.

3 = B.T.U. transmitted per square foot of surface per hour per degree difference of temperature between the gases outside the tubes and the water inside the tubes. As the coldest gas is at that end of the economizer at which the cold water enters and the hottest gas at the end where the water is hottest, there can be but little error in taking the difference of the mean temperatures of the gas and of the water.

$$30\ (t_h - t_c) = \left(\frac{T_h + T_c}{2} - \frac{t_h + t_c}{2}\right) \times 3 \times S$$

$$t_h = \frac{20\ t_c + 2\ S\ T_h + .562\ S\ t_c}{20 + 2.562\ S}$$

The Green Economizer Company use the following formula:

$$t_h - t_c = \frac{S\ (T_h - t_c)}{9.1 + \frac{(5\ w + GC)\ S}{2\ GC}}$$

In this w = pounds of feed water per boiler H. P.
G = pounds of flue gas per pound of combustible.
C = pounds of coal per boiler H. P. hour.

This formula is practically the same as the one already worked out.

Example

Flue gas leaves the boiler and enters the economizer at 550°F. The feed water after passing through both a primary and a secondary heater enters the economizer at 200° F. What is the temperature of the feed water leaving the economizer?

What is the temperature of the flue gases leaving the economizer?

It is customary to provide from 3.5 to 5 sq. ft. of heating surface in an economizer per boiler H. P. Assume in this case 4 sq. ft.

$$t_h = \frac{20 \times 200 + 2 \times 550 \times 4 + .562 \times 4 \times 200}{20 + 2.562 \times 4}$$

$$t_h = 292°$$

$$T_c = 550 - 1.562\ (292 - 200) = 407°$$

The feed water is heated from 200° to 292° by the economizer. Suppose the boiler pressure carried in a battery of boilers to have been 164.8 lbs. ab. with 100° superheat, then the heat needed to make a pound of water at 200° F. into superheated steam of pressure and conditions specified is 1252 − 168 = 1084 B. T. U.

The economizer saved 92 B. T. U. per lb. of water or $\frac{92}{1084}$ = .0849 say 8½ per cent. On a coal consumption of 592 tons per week with coal at $4.20 per ton a saving of 8½ per cent amounts in the course of a year to

$$.085 \times 592 \times 52 \times \$4.20 = \$10,989$$

The economizer consisting of 672 tubes cost at $12.00 a tube, $8,064; the piping etc. brought the cost up to $10,000.

There should be charged against the economizer which may be assumed to be worn out in 20 years, a certain percentage for depreciation (see later pages) which we will take as 3.02 per cent, interest 5 per cent, taxes 1.5 per cent, insurance 0.5 per cent and repairs 2.5 per cent making a total of 12.52 per cent.

$$.1252 \times \$10,000 = \$1,252$$

The saving apparently amounts to 10,989 − 1,252 = $9,737 per year.

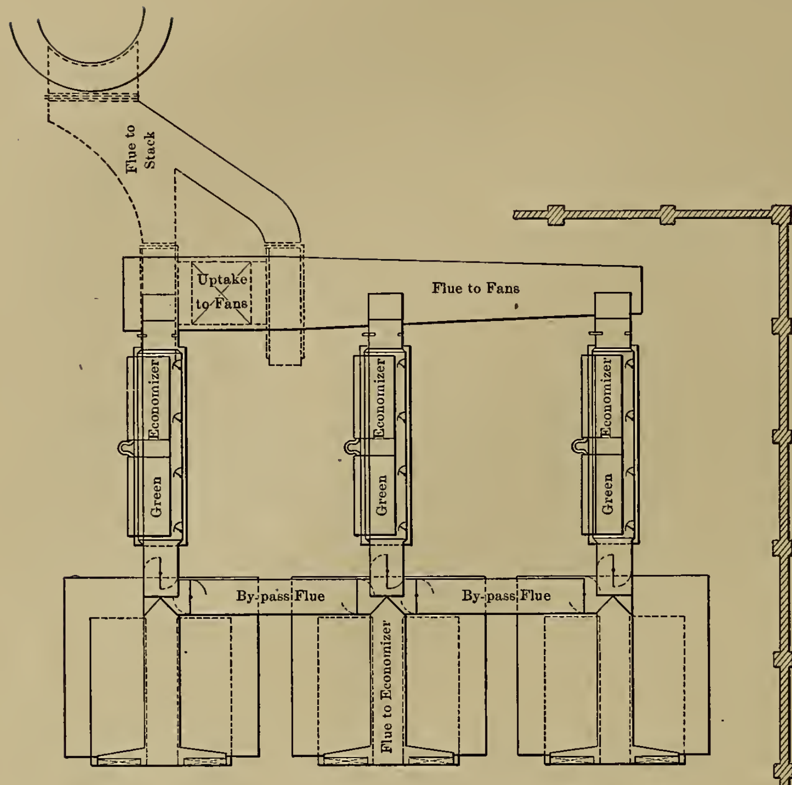
If an induced draft had to be maintained there should be charged against the economizer the cost of running the fan and the interest, depreciation, etc. on the cost of the outfit.

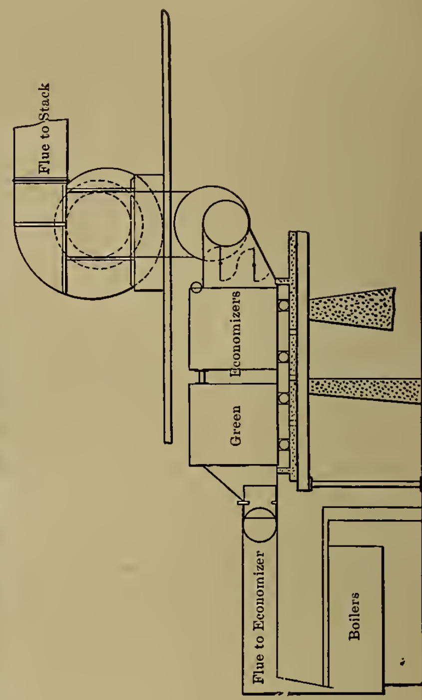
This would make the saving less. In spite of the fact that figures show a decided saving made by the use of an economizer many engineers will not recommend their installation.

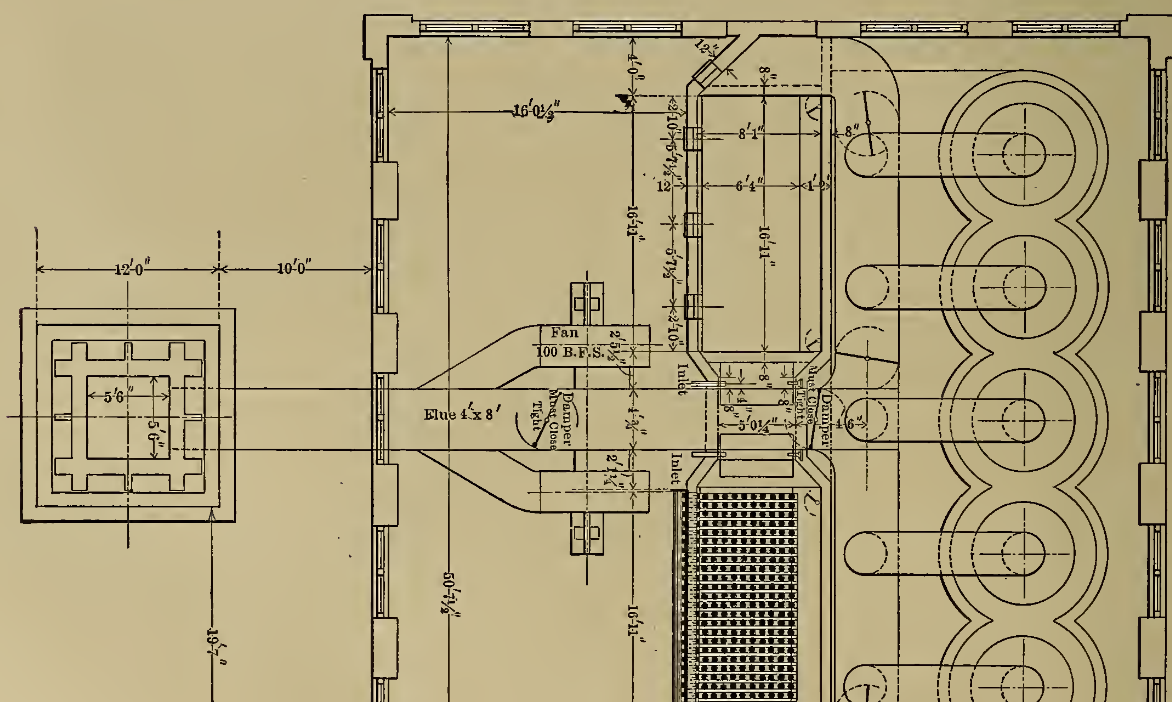
Some arrangements of economizers follow:

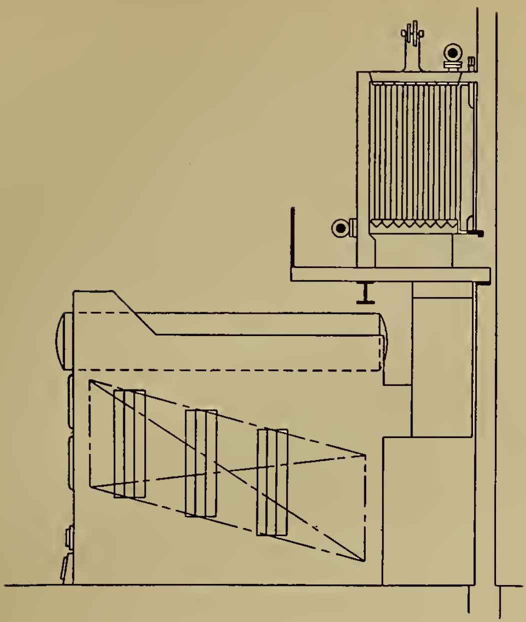
The resistance offered to the flue gases by an economizer amounts to from .25″ to 30″ of water. In many instances on account of this loss of draft, it becomes necessary to install an induced draft fan.

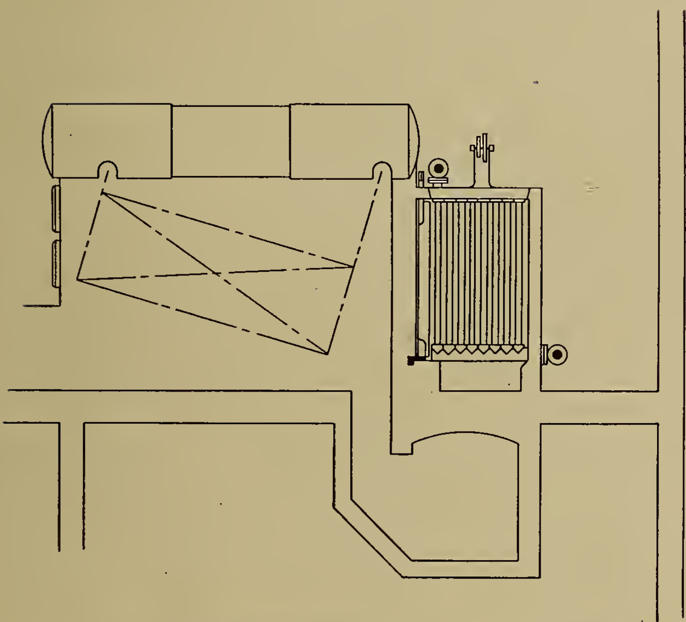
Illustrations of induced fan cutfits as erected in two manufacturing plants are shown.

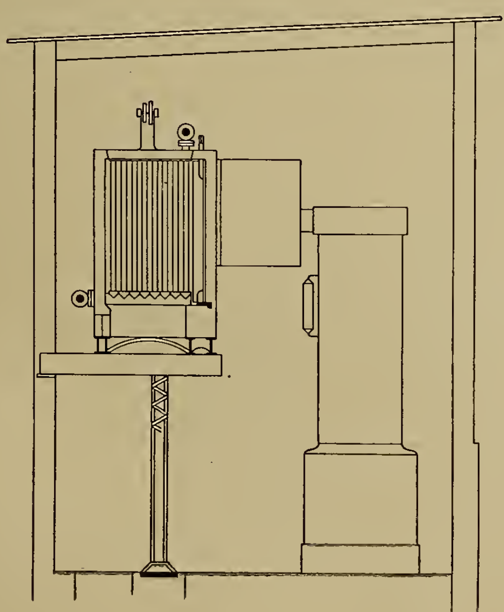

Flue to Stack
Uptake to Fans
Flue to Fans
Economizer
Green
Economizer
Green
Economizer
Green
By-pass Flue
By-pass Flue
Flue to Economizer

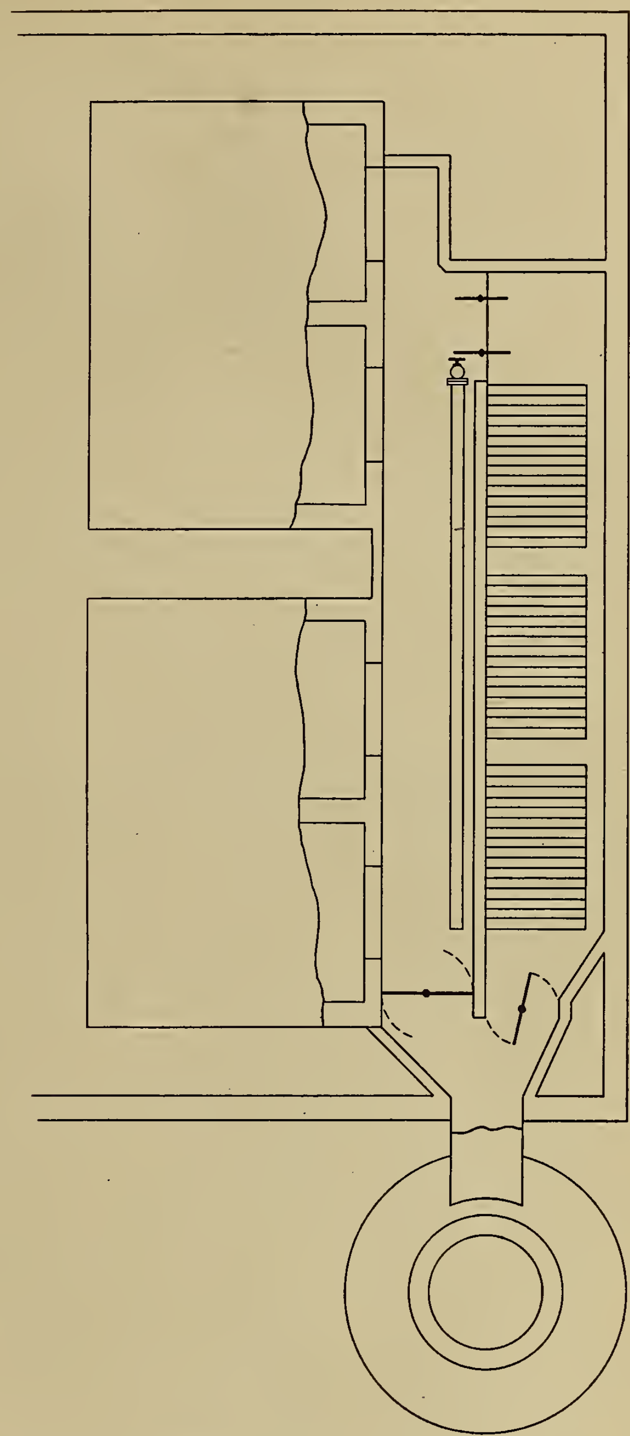

Flue to Stack
Economizers
Green
Flue to Economizer
Boilers

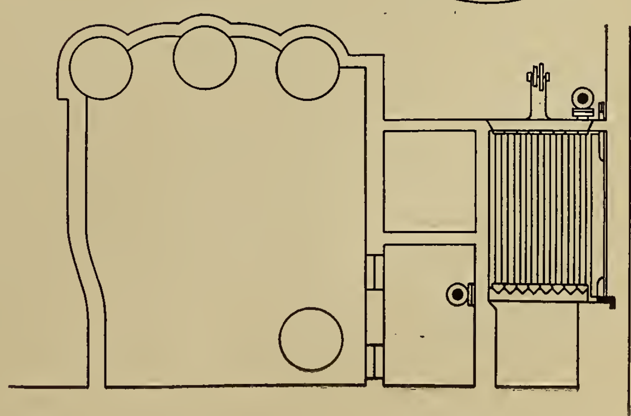

12′0″
10′0″
5′6″
5′6″
19′7″
16′0½″
Fan 100 B.F.S.
Flue 4′x 8′
Damper
Inlet
Inlet
Damper
50′0″











GENERAL DIMENSIONS OF GREEN'S IMPROVED FUEL ECONOMIZERS

Height over gearing, 13 ft. 5¼ in. Height over section, 10 ft. 2¼ in.

Number of Tubes	Number of Tubes Wide	Number of Rows	Length over Economizer	Dimensions Inside Walls			Area Between Tubes			Capacity in Pounds of Water	External Heating Surface
				Without Side Dampers	With One Side Damper	With Two Side Dampers	Without Side Dampers	With One Side Damper	With Two Side Dampers		
32	4	8	4′–10″	3′–4″	4′–1″	4′ 10″	16.6	23.85	31.10	1984	408
48	4	12	7′– 3″	"	"	"	"	"	"	2976	612
64	4	16	9′– 8″	"	"	"	"	"	"	3968	816
80	4	20	12′– 1″	"	"	"	"	"	"	4960	1020
96	4	24	14′– 6″	"	"	"	"	"	"	5952	1224
112	4	28	16′–11″	"	"	"	"	"	"	6944	1428
128	4	32	19′– 4″	"	"	"	"	"	"	7936	1632
144	4	36	21′– 9″	"	"	"	"	"	"	8928	1836
160	4	40	24′– 2″	"	"	"	"	"	"	9920	2040
176	4	44	26′– 7″	"	"	"	"	"	"	10912	2244
192	4	48	29′– 0″	"	"	"	"	"	"	11904	2448
208	4	52	31′– 5″	"	"	"	"	"	"	12896	2652
48	6	8	4′–10″	4′–8″	5′–5″	6′– 2″	21.85	29.10	36.35	2976	612
72	6	12	7′– 3″	"	"	"	"	"	"	4464	918
96	6	16	9′– 8″	"	"	"	"	"	"	5952	1224
120	6	20	12′– 1″	"	"	"	"	"	"	7440	1530
144	6	24	14′– 6″	"	"	"	"	"	"	8928	1836
168	6	28	16′–11″	"	"	"	"	"	"	10416	2142
192	6	32	19′– 4″	"	"	"	"	"	"	11904	2448
216	6	36	21′– 9″	"	"	"	"	"	"	13392	2754
240	6	40	24′– 2″	"	"	"	"	"	"	14880	3060
264	6	44	26′– 7″	"	"	"	"	"	"	16368	3366
288	6	48	29′– 0″	"	"	"	"	"	"	17856	3672
312	6	52	31′– 5″	"	"	"	"	"	"	19344	3978
336	6	56	33′–10″	"	"	"	"	"	"	20832	4284
360	6	60	36′– 3″	"	"	"	"	"	"	22320	4590
96	8	12	7′– 3″	6′–0″	6′–9″	7′– 6″	27.00	34.25	41.5	5952	1224
128	8	16	9′– 8″	"	"	"	"	"	"	7936	1632
160	8	20	12′– 1″	"	"	"	"	"	"	9920	2040
192	8	24	14′– 6″	"	"	"	"	"	"	11904	2448
224	8	28	16′–11″	"	"	"	"	"	"	13888	2856
256	8	32	19′– 4″	"	"	"	"	"	"	15872	3264
288	8	36	21′– 9″	"	"	"	"	"	"	17856	3672
320	8	40	24′– 2″	"	"	"	"	"	"	19840	4080
352	8	44	26′– 7″	"	"	"	"	"	"	21824	4488
384	8	48	29′– 0″	"	"	"	"	"	"	23808	4896
416	8	52	31′– 5″	"	"	"	"	"	"	25792	5304
448	8	56	33′–10″	"	"	"	"	"	"	27776	5712
480	8	60	36′– 3″	"	"	"	"	"	"	29760	6120
160	10	16	9′– 8″	7′–4″	8′–1″	8′–10″	32.25	39.50	46.75	9920	2040
200	10	20	12′– 1″	"	"	"	"	"	"	12400	2550
240	10	24	14′– 6″	"	"	"	"	"	"	14880	3060
280	10	28	16′–11″	"	"	"	"	"	"	17360	3570
320	10	32	19′– 4″	"	"	"	"	"	"	19840	4080
360	10	36	21′– 9″	"	"	"	"	"	"	22320	4590
400	10	40	24′– 2″	7′–4″	8′–1″	8′–10″	32.25	39.50	46.75	24800	5100
440	10	44	26′– 7″	"	"	"	"	"	"	27780	5610
480	10	48	29′– 0″	"	"	"	"	"	"	29780	6120
520	10	52	31′– 5″	"	"	"	"	"	"	32240	6630
560	10	56	33′ 10″	"	"	"	"	"	"	34720	7140
600	10	60	36′– 3″	"	"	"	"	"	"	37200	7650
640	10	64	38′– 8″	"	"	"	"	"	"	39680	8160
680	10	68	41′– 1″	"	"	"	"	"	"	42160	8670
720	10	72	43′– 6″	"	"	"	"	"	"	44640	9180
760	10	76	45′–11″	"	"	"	"	"	"	47120	9690
800	10	80	48′– 4″	"	"	"	"	"	"	49600	10200
240	12	20	12′– 1″	8′–8″	9′–6″	10′- 3″	39.25	44.75	51.50	14880	3060
288	12	24	14′– 6″	"	"	"	"	"	"	17856	3672
336	12	28	16′–11″	"	"	"	"	"	"	20832	4284
384	12	32	19′– 4″	"	"	"	"	"	"	23808	4896
432	12	36	21′– 9″	"	"	"	"	"	"	26784	5508
480	12	40	24′– 2″	"	"	"	"	"	"	29760	6120
528	12	44	26′– 7″	"	"	"	"	"	"	32736	6732
576	12	48	29′– 0″	"	"	"	"	"	"	35712	7344
624	12	52	31′– 5″	"	"	"	"	"	"	38688	7956
672	12	56	33′–10″	"	"	"	"	"	"	41664	8568
720	12	60	36′– 3″	"	"	"	"	"	"	44640	9180
768	12	64	38′– 8″	"	"	"	"	"	"	47616	9792
816	12	68	41′– 1″	"	"	"	"	"	"	50592	10404
864	12	72	43′– 6″	"	"	"	"	"	"	53568	11016

Standard Sizes of Sturtevant Standard Economizers.

Machine Number.	Number of Pipes.	Number of Sections.	No. of Pipes in Section.	External Heating Surface. Sq. ft.	Capacity in Pounds of Water.	General Dimensions. Length ft. in.	Width ft. in.	Height in ft. and in. Section.	Height in ft. and in. Section and Gearing.
1	32	8	4	400	2016	4—10	3—2½	10—2¼	12—6
2	48	12	4	600	3024	7— 3	"	"	"
3	64	16	4	801	4032	9— 8	"	"	"
4	80	20	4	1001	5040	12— 1	"	"	"
5	96	24	4	1201	6048	14— 6	"	"	"
6	112	28	4	1401	7056	16—11	"	"	"
7	128	32	4	1601	8064	19— 4	"	"	"
8	40	8	5	499	2520	4—10	3—10½	"	"
9	60	12	5	749	3780	7— 3	"	"	"
10	80	16	5	999	5040	9— 8	"	"	"
11	100	20	5	1248	6300	12— 1	"	"	"
12	120	24	5	1499	7560	14— 6	"	"	"
13	140	28	5	1747	8820	16—11	"	"	"
14	160	32	5	1997	10080	19— 4	"	"	"
15	180	36	5	2247	11340	21— 9	"	"	"
16	200	40	5	2496	12600	24— 2	"	"	"
17	72	12	6	897	4536	7— 3	4—6½	"	"
18	96	16	6	1196	6048	9— 8	"	"	"
19	120	20	6	1496	7560	12— 1	"	"	"
20	144	24	6	1795	9072	14— 6	"	"	"
21	168	28	6	2094	10584	16—11	"	"	"
22	192	32	6	2393	12096	19— 4	"	"	"
23	216	36	6	2692	13608	21— 9	"	"	"
24	240	40	6	2991	15120	24— 2	"	"	"
25	264	44	6	3290	16632	26— 7	"	"	"
26	288	48	6	3589	18144	29— 0	"	"	"
27	112	16	7	1394	7056	9— 8	5—2½	"	"
28	140	20	7	1743	8820	12— 1	"	"	"
29	168	24	7	2092	10584	14— 6	"	"	"
30	196	28	7	2440	12348	16—11	"	"	"
31	224	32	7	2789	14112	19— 4	"	"	"
32	252	36	7	3137	15876	21— 9	"	"	"
33	280	40	7	3486	17640	24— 2	"	"	"
34	308	44	7	3835	19404	26— 7	"	"	"
35	336	48	7	4183	21168	29— 0	"	"	"
36	364	52	7	4532	22932	31— 5	"	"	"
37	392	56	7	4880	24696	33—10	"	"	"
38	128	16	8	1592	8064	9— 8	5—10½	"	"
39	160	20	8	1990	10080	12— 1	"	"	"
40	192	24	8	2388	12096	14— 6	"	"	"
41	224	28	8	2786	14112	16—11	"	"	"
42	256	32	8	3185	16128	19— 4	"	"	"
43	288	36	8	3583	18144	21— 9	"	"	"
44	320	40	8	3981	20160	24— 2	"	"	"
45	352	44	8	4379	22176	26— 7	"	"	"
46	384	48	8	4777	24182	29— 0	"	"	"
47	416	52	8	5175	26198	31— 5	"	"	"
48	448	56	8	5573	28224	33—10	"	"	"
49	480	60	8	5971	30240	36— 3	"	"	"

Machine Number.	Number of Pipes.	Number of Sections.	No of Pipes in Section.	External Heating Surface. Sq. ft	Capacity in Pounds Water	General Dimensions. Length ft. in	Width ft in	Height in ft and in Section.	Height in ft and in Section and Gearing
50	180	20	9	2237	11340	12— 1	6—6½	10—2¼	12—6
51	216	24	9	2685	13608	14— 6	"	"	"
52	252	28	9	3132	15876	16—11	"	"	"
53	288	32	9	3580	18144	19— 4	"	"	"
54	324	36	9	4027	20412	21— 9	"	"	"
55	360	40	9	4475	22680	24— 2	"	"	"
56	396	44	9	4922	24948	26— 7	"	"	"
57	432	48	9	5370	27216	29— 0	"	"	"
58	468	52	9	5817	29484	31— 5	"	"	"
59	504	56	9	6265	31752	33—10	"	"	"
60	540	60	9	6712	34020	36— 3	"	"	"
61	576	64	9	7160	36288	38— 8	"	"	"
62	200	20	10	2484	12600	12— 1	7—2½	"	"
63	240	24	10	2981	15120	14— 6	"	"	"
64	280	28	10	3478	17640	16—11	"	"	"
65	320	32	10	3974	20160	19— 4	"	"	"
66	360	36	10	4471	22680	21— 9	"	"	"
67	400	40	10	4968	25200	24— 2	"	"	"
68	440	44	10	5465	27720	26— 7	"	"	"
69	480	48	10	5962	30240	29— 0	"	"	"
70	520	52	10	6458	32760	31— 5	"	"	"
71	560	56	10	6955	35280	33—10	"	"	"
72	600	60	10	7452	37800	36— 3	"	"	"
73	640	64	10	7949	40320	38— 8	"	"	"
74	680	68	10	8446	42840	41— 1	"	"	"
75	396	36	11	4915	24949	21— 9	7—10½	"	"
76	440	40	11	5461	27720	24— 2	"	"	"
77	484	44	11	6008	30497	26— 7	"	"	"
78	528	48	11	6554	33268	29— 0	"	"	"
79	572	52	11	7101	36045	31— 5	"	"	"
80	616	56	11	7646	38811	33—10	"	"	"
81	660	60	11	8193	41588	36— 3	"	"	"
82	704	64	11	8739	44359	38— 8	"	"	"
83	748	68	11	9286	47136	41— 1	"	"	"
84	792	72	11	9832	49907	43— 6	"	"	"
85	836	76	11	10379	52684	45—11	"	"	"
86	880	80	11	10925	55455	48— 4	"	"	"
87	528	44	12	6549	33262	26— 7	8—6½	"	"
88	576	48	12	7145	36289	29— 0	"	"	"
89	624	52	12	7741	39317	31— 5	"	"	"
90	672	56	12	8337	42344	33—10	"	"	"
91	720	60	12	8933	45371	36— 3	"	"	"
92	768	64	12	9529	48398	38— 8	"	"	"
93	816	68	12	10125	51425	41— 1	"	"	"
94	864	72	12	10721	54452	43— 6	"	"	"
95	912	76	12	11317	57479	45—11	"	"	"
96	960	80	12	11913	60506	48— 4	"	"	"
97	1008	84	12	12489	63432	50— 9	"	"	"
98	1056	88	12	13065	66357	53— 2	"	"	"

MECHANICAL STOKERS

There is no question about the desirability of mechanical stokers in a plant of 1500 H. P.

While there may not be any saving in the cost of labor on a plant of 1500 H. P. the protection against labor troubles which a stoker affords warrants its use on a plant of this size.

On plants of larger size the saving in labor, together with the increased capacity to be obtained from the boilers, the freedom from smoke troubles, the insurance against labor troubles and the ability to push a boiler from a banked condition to 150 per cent rating in ten minutes make stokers absolutely necessary.

The stokers may be divided into classes:

(1) The Taylor and The Riley underfed stokers, both similar to the cut following.

(2) The Murphy and the Roney, inclined grates.

(3) The chain grate, like Green, Keystone, and the Babcock & Wilcox.

(4) The American; The Jones; both underfed stokers but differing from the Riley and the Taylor.

There are others not mentioned, the ones named being those most commonly found.

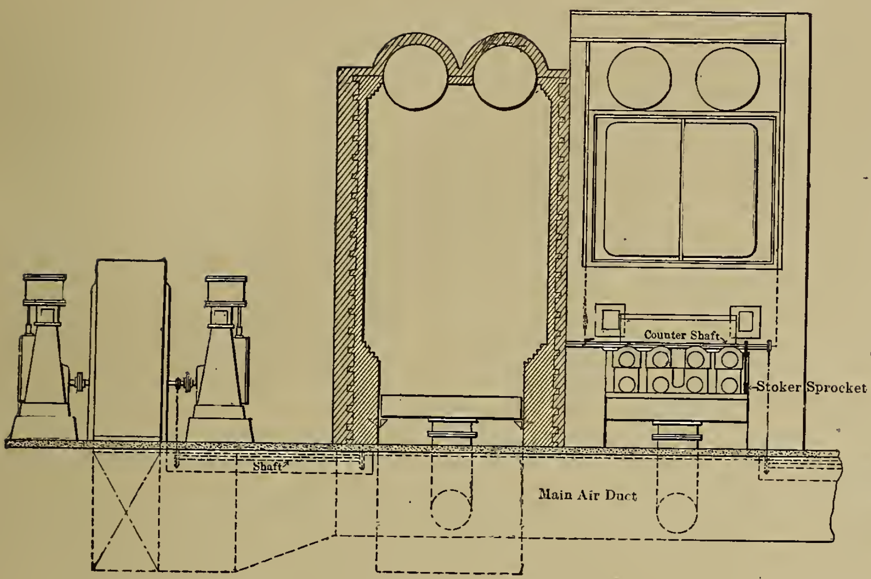
The Taylor and the Riley are both capable of quick forcing and can be crowded harder than the Murphy or the Roney. All four of these are best suited for a good grade of soft coal. The chain grate works best on a poorer grade of coal.

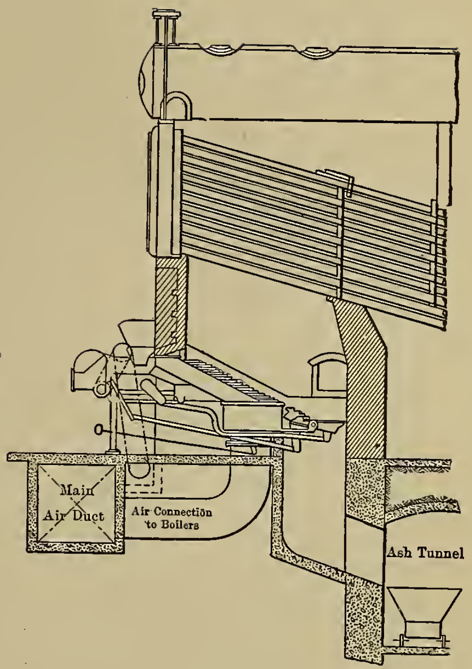
The American and The Jones are better suited for small units than for large units.

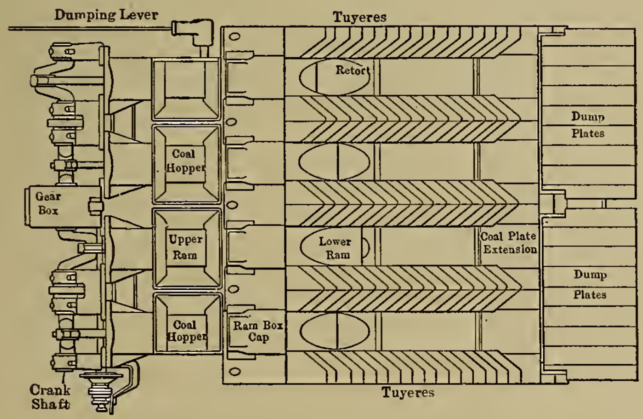
Stokers cost from $6 to $10 per rated H. P. of the boiler. The higher figure includes the cost of the fan and engine required by certain types of stoker.

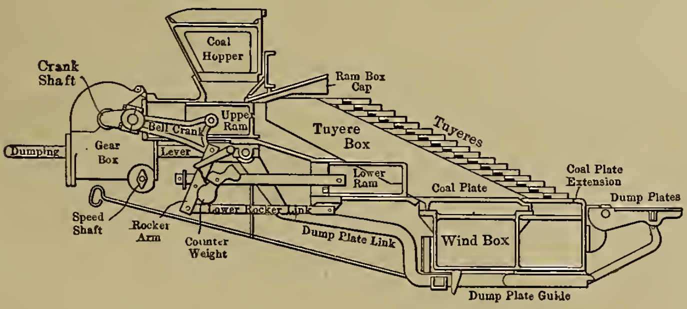
See Steam Boilers, Peabody and Miller for more detailed discussion of stokers.

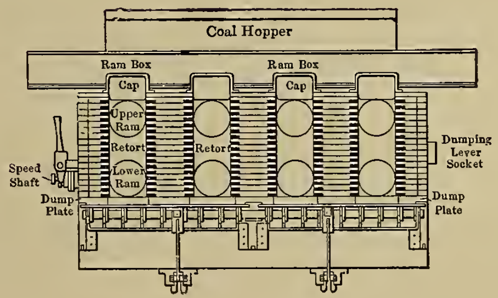
The life of a stoker is from 6 to 8 years, consequently a high rate for depreciation must be charged against it.


Counter Shaft
Stoker Sprocket
Shaft
Main Air Duct


Main Air Duct
Air Connection to Boilers
Ash Tunnel


Dumping Lever
Tuyeres
Retort
Dump Plates
Coal Hopper
Gear Box
Upper Ram
Lower Ram
Coal Plate Extension
Dump Plates
Coal Hopper
Ram Box Cap
Crank Shaft
Tuyeres


Coal Hopper
Crank Shaft
Ram Box Cap
Upper Ram
Bell Crank
Tuyere Box
Tuyeres
Dumping
Gear Box
Lever
Lower Ram
Coal Plate
Coal Plate Extension
Dump Plates
Speed Shaft
Rocker Arm
Lower Rocker Link
Counter Weight
Dump Plate Link
Wind Box
Dump Plate Guide


Coal Hopper
Ram Box
Ram Box
Cap
Cap
Upper Ram
Retort
Retort
Lower Ram
Dumping Lever Socket
Speed Shaft
Dump Plate
Dump Plate

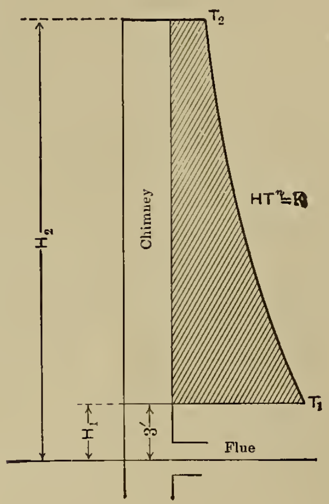
CHIMNEYS, FLUES AND DRAUGHTS

The draft of a chimney depends upon the temperature of the gases entering the chimney, the temperature of the gases leaving the chimney, the height of the chimney and the temperature of the outside air.

In figuring the draft, an average temperature of the outside air may be taken as 55°.

As the draught of a chimney is due to the difference in weight of a column of cold air of the height of the chimney and the column of hot gas in the chimney, in order to figure the draft it is necessary to know the mean temperature inside the chimney.

From work done on three or four chinmeys from 3′ dia. 100 ft. tall to 16′ dia. 250 ft. tall, the variation in temperature throughout the height of a stack has been plotted and an equation of the form $HT^n = K$ fitted to the curve.



H = height in feet of chimney at any point above middle of flue, the lower value of H being 3 ft.
T = absolute temperature in degrees F.
T_1 = absolute temperature of gases entering chimney.
$N = 25$ $\log K = 75.4032$

The mean absolute temperature is equal to

$$\frac{\text{area crosshatched}}{H_2 - 3}$$

This equals

$$\frac{\frac{T_1 \times 75}{24}\left\{\left(\frac{H_2}{3}\right)^{\frac{24}{25}} - 1\right\}}{H_2 - 3}$$

Example: Assume temp. at a level 3 ft. above centre of flue as 1000° ab. Top of chimney 231 ft. above centre of flue. Find mean temperature and probable draft when outside air is at 55° F.

$$\frac{\frac{1000 \times 75}{24}\left\{\left(\frac{231}{3}\right)^{\frac{24}{25}} - 1\right\}}{231 - 3} = 873.0$$

$$\frac{11.78 \times 14.7}{491.5} = \frac{v\,(14.7 - .6 \times .04)}{873}$$

$v = 20.96$ $\frac{1}{v} = .0477$

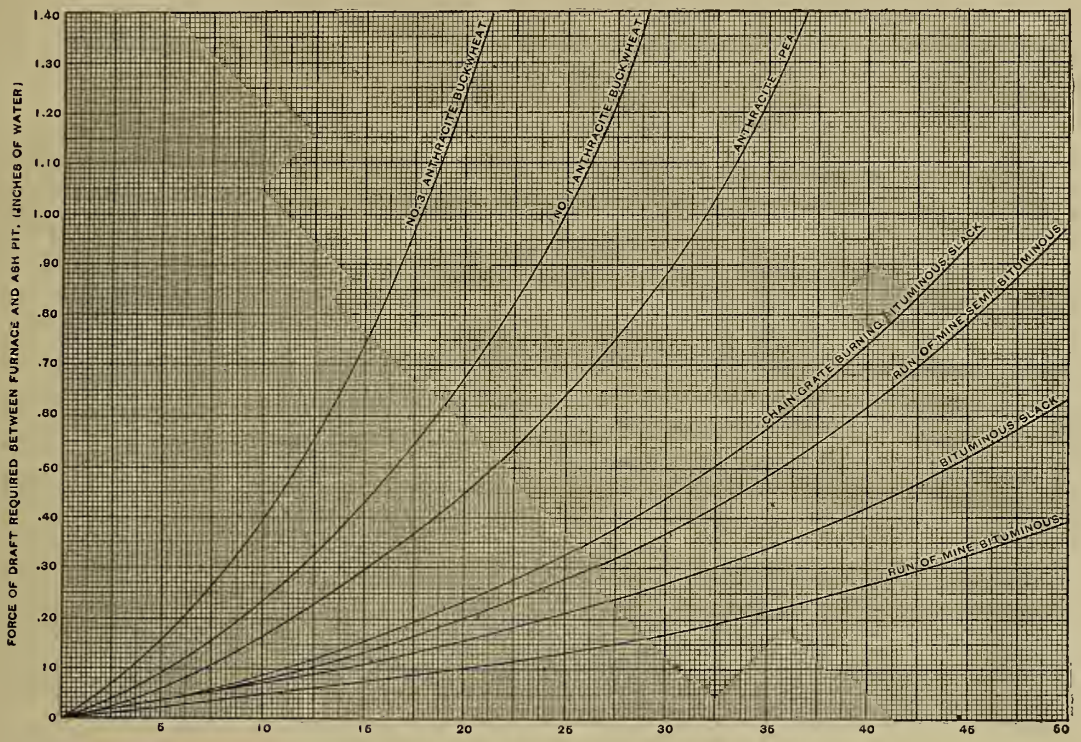
$$\frac{12.39 \times 14.7}{491.5} = \frac{v \times 14.7}{459.5 + 55}$$ $v = 12.97$ $\frac{1}{v} = .0771$

$$\frac{(.0771 - .0477)\,(231 - 3) \times 12}{62.4} = 1.29$$

In the preceding calculation, the pressure in the chimney was needed, this was assumed to be (14.7 − .6 × .04) or the draft was assumed to be 1.20″ at the bottom of the chimney.

11.78 is the specific volume of flue gas.
12.39 the specific volume of air.

The draught at the boiler will be less than that at the chimney end of the uptake on account of friction in the uptake, bends, etc. Generally .10″ loss of draught is allowed for each 100 ft. of flue and .05″ for each right angle bend. In addition to this there is from .25 to .3″ lost due to resistance offered by the tubes of the boiler. In addition to this there is the resistance offered by the fuel bed and the grates.



CURVES SHOWING DRAFT REQUIRED BETWEEN FURNACE AND ASH-PIT AT DIFFERENT COMBUSTION RATES FOR VARIOUS KINDS OF COAL

The amount of draft needed, or the loss of draft between the furnace and the ash pit, for different kinds of coal burned at different rates has been determined by the Stirling Boiler Company from actual tests.

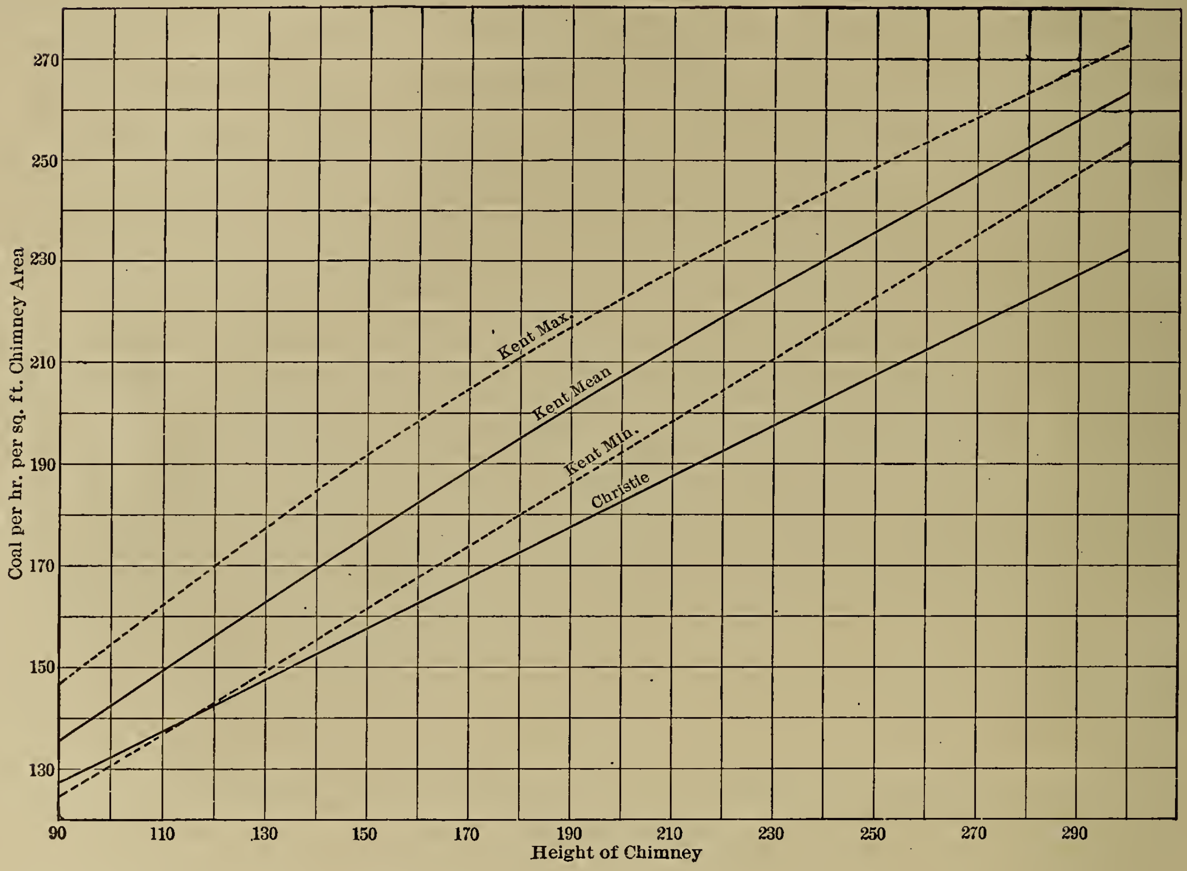
The accompanying plot taken from their work needs no explanation.

Example required draft needed at base of stack by a boiler 200 feet from chimney with 2 sharp bends in flue, the boiler burning run of mine bituminous coal at a rate of 25 lbs. of coal per square foot of grate per hour.

Loss of draft between furnace and ash pit (plot)	= .13″
200 ft. flue loss	= .20″
2 sharp bends loss	= .10″
Loss due to tubes and passages in boiler .	= .30″
	.73″

EXAMPLE: A boiler plant has a chain grate burning 30 pounds of bituminous slack coal per square foot of grate per hour, a unit economizer and about 100 feet of flue. What should be the draft produced by the chimney?

Boiler resistance	.25
Economizer resistance	.30
100 ft. flue	.10
2 right angle bends	.10
Resistance through grate	.44
Draft required	1.19



With Taylor or Riley underfed stokers the air is delivered through the fuel bed under pressures of 4″ to 6″ of water, whatever may be needed to maintain a balanced draft over the fire; the stack is by this means relieved of the resistance offered by the fuel bed and generally gives sufficient draft to pull through an economizer.

The gases after leaving an economizer are cooled and the draft of the chimney reduced because of the lower temperature.

It will be found that adding 25 feet to the height of a chimney does not increase the draft very much.

The dimensions of a chimney may be found with as great accuracy as is required by means of a chart which has been constructed from the tables of H. P. of chimneys given by Kent and by Christie (See Steam Boilers, Peabody & Miller). On this chart the capacities in lbs. of coal per hour per square foot of chimney area are given for different heights of chimney. Knowing the coal to be burned per hour, the cross sectional area for any assumed height may be calculated.

The ratio of height to cross section must be considered, otherwise a poorly proportioned chimney may be obtained.

For discussion of the stability of a chimney see Steam Boilers. In general the maximum compression due to both dead load and wind pressure is not allowed to exceed 10 tons per square foot.

FEED PUMPS FOR BOILERS

STEAM CONSUMPTION OF PUMPS

The steam consumption of a duplex pump varies with the speed at which the pump runs.

At half speed or at one-half rated capacity 125 to 150 pounds of steam will in general be required per horse power hour of water work done.

For slower speeds the rate may become as large as 200 or 250 lbs. At full speed and at rated capacity 90 to 100 pounds is a fair value to use for the steam consumption per water horse power per hour.

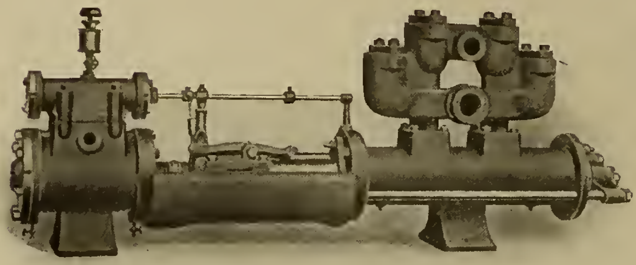
Turbine driven centrifugals are now quite generally used as feed pumps in the larger power plants.

The efficiency of a centrifugal pump designed for a given head and given capacity may reach 80 per cent, but under the conditions which apply to centrifugals used as feed pumps a value between 40 and 55 per cent should be used. The steam consumption for the driving end may be obtained from the curves already given.

Drawings and table of dimensions of the Terry steam turbine with centrifugal feed pump are given on page 39.

THE KNOWLES HORIZONTAL DOUBLE ACTING PLUNGER PUMP. POT VALVE TYPE.

End packed for 300 lbs. working water pressure.
Center packed for 200 lbs. working water pressure.

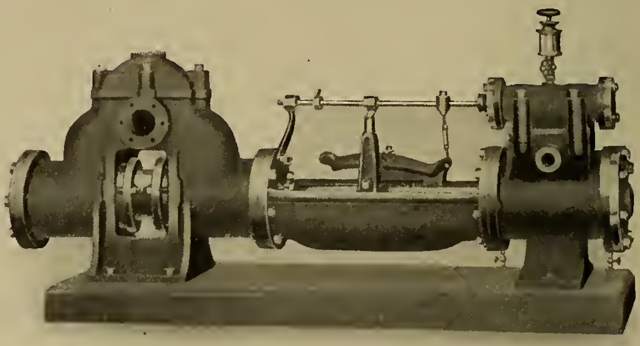


End Packed

Steam Cylinder Inches	Water Plungers Inches	Stroke Inches	Gallons per Stroke	Capacity per Minute at Maximum Speed: Strokes	Capacity per Minute at Maximum Speed: Gals.	Steam Pipe Inches	Exhaust Pipe Inches	Suction Pipe Inches	Delivery Pipe Inches	Floor Space Required Inches
4	2½	5	.11	150	16½	½	¾	1¼	1	57 x 10
5½	3¼	7	.25	125	31	¾	1	2	1½	72 x 12
6	3¾	7	.33	125	41	¾	1	2	1½	72 x 12
7½	3¾	10	.47	100	47	1	1¼	2	1½	92 x 12
7½	4½	10	.69	100	69	1	1¼	2½	2	92 x 12
8	5	10	.85	100	85	1	1¼	3	2½	92 x 12
8	4	12	.65	100	65	1	1¼	2½	2	112 x 12
8	5	12	1.02	100	102	1	1¼	3	2½	112 x 12
10	5	12	1.02	100	102	1¼	1½	3	2½	112 x 12
10	6	12	1.47	100	147	1¼	1½	3½	3	112 x 22
12	6	12	1.47	100	147	2	2½	3½	3	114 x 22
12	7	12	2.00	100	200	2	2½	5	4	120 x 27
14	7	12	2.00	100	200	2	2½	5	4	120 x 27
14	8	12	2.61	100	261	2	2½	6	5	124 x 27
16	8	12	2.61	100	261	2½	3	5	4	124 x 28
16	8	18	3.91	67	261	2½	3	6	5	164 x 30
16	9	18	4.96	67	332	2½	3	8	6	164 x 30
18	9	18	4.96	67	332	2½	3	8	6	172 x 30

Center Packed

4½	2⅜	6	.11	150	16.5	½	¾	1¼	1	68 x 10
4½	2¾	6	.15	150	22.5	½	¾	1¼	1	68 x 10
5½	3¼	7	.25	125	31.	¾	1	2	1½	72 x 12
6	3¾	7	.33	125	41.	¾	1	2	1½	72 x 12
6½	4⅛	8	.46	125	57.5	¾	1¼	2½	2	75 x 12
7½	4½	10	.69	100	69.	1	1¼	2½	2	89 x 14
8	5	10	.85	100	85.	1	1¼	3	2½	89 x 14
8	5	12	1.02	100	102.	1	1¼	3	2½	96 x 14
10	6	12	1.47	100	147.	1¼	1½	3½	3	98 x 22
12	7	12	2.00	100	200.	2	2½	5	4	100 x 27
14	8	12	2.61	100	261.	2	2½	5	4	102 x 27
16	9	18	4.96	67	332.	2½	3	8	6	136 x 30

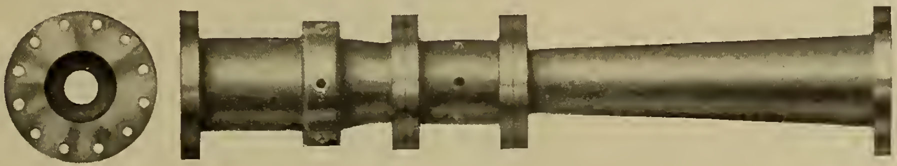


In an emergency the capacities of these pumps can be doubled. For continuous work such as boiler feeding, speeds and capacities one half of those given are recommended.

THE VENTURI METER

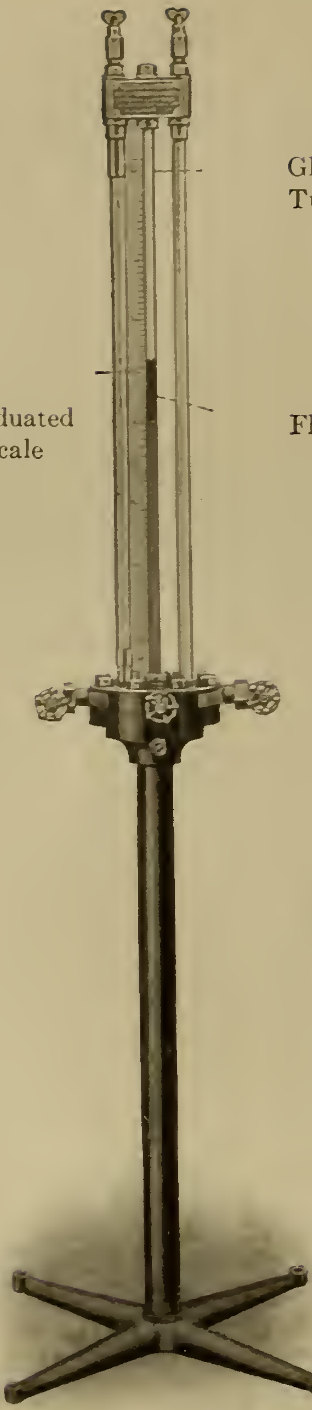
Nearly every large power plant has a Venturi meter in the boiler feed pipe. This meter may have a recording indicator or simply a Venturi meter manometer. The table following gives the sizes of the meters for boiler feed pipes as made by the Builders Iron Foundry of Providence, R. I.

The Venturi meter manometer contains a well filled with mercury into which a glass tube dips. The higher pressure from the inlet of the Venturi is conducted to the top of the mercury surface, and the lower pressure from the throat of the meter to the interior of the glass tube. The difference in these two pressures is indicated by the height of the single column of mercury within the glass tube. The rate of flow for any difference of pressures can be read opposite the surface of the mercury of the inner tube from the graduated scale shown at the left. The total quantity of water flowing may be obtained by taking readings periodically, averaging the same and multiplying the average by the elapsed time. The manometer is not suitable for installations where the rate of flow changes rapidly. For such cases the recording indicator shown would be preferable.



Extra heavy meter tubes with "Manufacturers Standard" flange ends are usually selected for hot water. These are adapted to pre sures up to 250 pounds per square inch.

Inches Diameter of Pipe	Catalog Number	Length of Meter Tube	Boiler Horse Power 30 lbs. per H. P. per hour		Pounds per Hour		Gallons per Minute	
			Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
2	2⅝	1'-11⅞"	45	590	1360	17600	3	35
	2¾	1'-10¼"	65	850	1960	25400	4	50
	21	1'-7"	115	1500	3470	45100	7	90
2½	2½A	2'-4⅝"	85	1150	2660	34500	5	70
	2½B	2'-3"	115	1500	3470	45100	7	90
	2½C	1'-11¾"	180	2350	5420	70400	11	140
3	31	2'-11"	115	1500	3470	45100	7	90
	31¼	2'-7¾"	180	2350	5420	70400	11	140
	31½	2'-4½"	260	3380	7820	102000	16	205
4	41¼	4'-3¾"	180	2350	5420	70400	11	140
	41⅝	3'-10⅞"	305	4000	9170	119000	18	240
	42	3'-6"	465	6000	13900	181000	28	360
5	51⅝	5'-1⅜"	305	4000	9170	119000	18	240
	52	4'-8½"	465	6000	13900	181000	28	360
	52½	4'-2"	725	9400	21700	282000	43	560
6	62	5'-11"	465	6000	13900	181000	28	360
	62½	5'-4½"	725	9400	21700	282000	43	560
	63	4'-10"	1040	13600	31300	406000	63	810
8	82¾	7'-6¼"	870	11300	26500	344000	53	680
	83¼	6'-11¾"	1230	16000	36600	476000	73	950
	84	6'-2"	1850	24100	55600	722000	111	1440
10	103¼	9'-4¾"	1230	16000	36600	476000	73	950
	104	8'-7"	1850	24100	55600	722000	111	1440
	105	7'-6"	2900	37600	86900	1129000	174	2260
12	124	11'-0"	1850	24100	55600	722000	111	1440
	125	9'-11"	2900	37600	86900	1129000	174	2260
	126	8'-10"	4200	54200	125000	1626000	250	3250



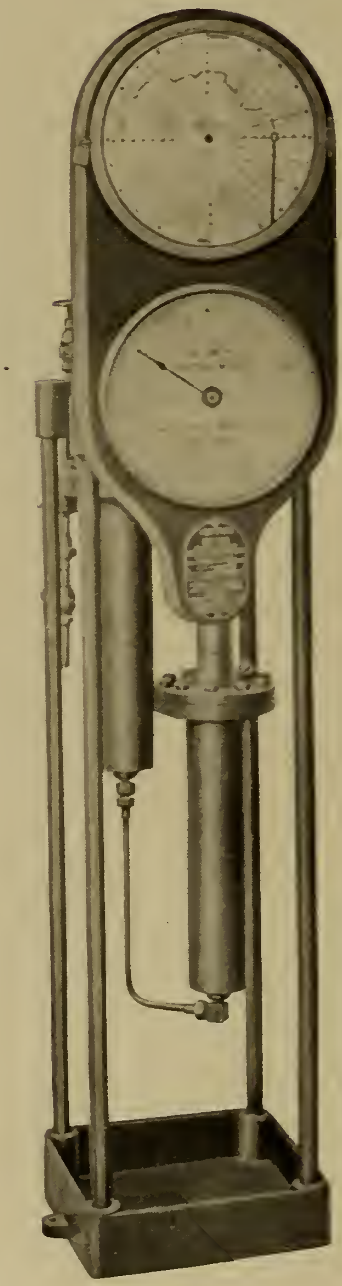


CHART RECORDER DIAL
(Continuously records the rate of flow)

INDICATOR DIAL
(Shows the present rate of flow)

DIMENSIONS, Etc.
Base — 16 inches square
Height — 6½ feet
Shipping Weight — 500 lbs.

CALIBRATION TESTS ON METERS IN SERVICE

Test No. 1. Made at Worcester Polytechnic Institute on 4-inch meter tube No. 2319, 1⅝ inch throat, equipped with manometer. Water was pumped through the meter tube into a very large wooden tank resting on platform scales, which form a part of the regular laboratory equipment. The manometer was placed on the floor immediately below the meter tube to which it was connected by flexible pipes. The rated capacity of this meter is 9,170 to 119,000 pounds per hour. The results were as follows:

Numbers of Tests	Pounds of Water Per Hour — Meter Manometer	Pounds of Water Per Hour — Actual Weight	Error of Meter Manometer
1	120,600	122,640	– 1.87%
2	90,000	89,820	+ 0.20%
3	59,950	59,940	+ 0.02%
4 and 5	30,000	29,370	+ 2.10%
6 and 7	9,000	8,950	+ 0.55%

Test No. 2. Four-inch Venturi Meter (1¼-inch throat) at the plant of the Woonsocket (Mass.) Electric Machine & Power Company. Water pumped by duplex feed pump to two barrels which were filled alternately, the weight of water which each would hold having been determined previously. The test lasted five hours and the flow was continuous.

Corrected weight of water by barrels	132,802 lbs.
Corrected weight of water by Venturi	131,000 lbs.

Difference, 1.35%.

Test No. 3. Four-inch Venturi Meter (1¼-inch throat) at plant of Brown & Sharpe Mfg. Company, Providence. Meter Tube was located on suction side of single plunger pump and course of water was from two calibrated open heaters (emptied alternately) to Meter Tube to pump.

Total pounds of water by heaters	392,453 lbs.
Total pounds of water by Venturi Meter	397,104 lbs.

Difference, 1.18%.

Duration of test, 10 hours.

A paper prepared by Prof. C. M. Allen presented before the A. S. M. E. gives a full discussion of the Venturi Meter as applied for measuring feed water.

ENGINES

STEAM CONSUMPTION OF ENGINES

The steam consumption of a simple non-condensing engine varies both with the cut-off and with the boiler pressure.

There is but little gain in raising the pressure on a simple engine above 150 lbs.

The variation in steam consumption per I. H. P. hour with the cut-off may be figured with reasonable accuracy from the full load consumption by multiplying the full load consumption by the following ratios:

Load	¼	½	¾	Full	1¼
Ratio	1.26	1.13	1.09	1	1.05

From tests on engines, of about the same type and size as the engine under consideration, working through the same ranges of pressure and temperature, from the same initial conditions, one can predict the probable performance with reasonable accuracy.

In the absence of such tests the cylinder efficiency of a single valve non-condensing engine working with steam under 150 lbs. absolute may be taken between 55 and 65 per cent, when working at its economical load. The cylinder efficiency of a four valve condensing engine may be taken at most economical load as from 66 to 72 per cent. The size of the engine, the valve gear, etc. all have an influence on the so-called "cylinder efficiency."

This cylinder efficiency multiplied by the Rankine efficiency and by the mechanical efficiency gives the overall efficiency from which the steam consumption may be calculated as explained later

CALCULATION OF POWER OF ENGINES

The mechanical efficiency of an engine or the ratio of the brake power to the indicated horse power is between 90 and 93 per cent.

The power of an engine at any speed and cut off may be found by drawing an indicator card using hyperbolae for expansion and compression lines, getting the M. E. P. from the card and then proceeding in the usual way.

For a compound or triple expansion engine the M. E. P. is calculated on the assumption that the entire pressure drop is to be obtained in the low pressure cylinder.

The ratio of cylinder volumes is
for compound engines H. to L. 1 to 2½ or 3
in some rare cases 1 to 7 or 8
for triple expansion engines H. to I. 1 to 3
I. to L. 1 to 3¼ or 3½
or H. to L. 1 to 9¾ or 10½.

A calculation for Horse Power, which will give results more or less in error depending upon the accuracy with which one knows the multiplier used in getting the actual M. E. P. from the calculated, may be made as follows:—

$$H.\,P. = \frac{\text{Calculated } M.\,E.\,P. \times \text{multiplier} \times D^2 \times .7854 \times 2 \times \text{Revs.} \times S}{33000}$$

D = dia. low pressure cylinder in inches
Revs. = revolutions per minute
P_1 = absolute initial pressure on a square inch
P_2 = back pressure absolute on a square inch

$$N = \text{No. of expansions} = \frac{D^2}{H^2 \times \text{cut-off}}$$

Cut-off is expressed as a decimal.

S = stroke in feet
H = dia. high in inches

$$\text{Calculated } M.E.P. = \frac{P_1}{N} + \frac{P_1}{N} 2.3026 \log_{10} N - P_2$$

CYLINDER EFFICIENCY OF STEAM ENGINES AND STEAM TURBINES

The ratio corresponding to the cylinder efficiency is for condensing turbine units about the same (*i. e.*, .60 to .72) as for condensing steam engines; for non-condensing turbine units, however, the ratio is much lower than for non-condensing engines, the value being .40 to .49 as against .55 to .65.

The higher the back pressure the lower the ratio becomes and .40 would apply for pressures of 50 to 70 lbs. absolute back pressure, .45 for back pressures about 35 lbs. absolute, and .49 for back pressures of 15 to 20 lbs. absolute.

From these figures it is at once evident that the non-condensing turbine working against back pressure cannot compete in economy with the better class of non-condensing reciprocating engines.

It is the custom in many manufacturing establishments to bleed steam from some stage of a turbine or from a receiver between the cylinders of a multiple expansion engine and to use this steam for industrial purposes. This is done rather than to draw live steam from the boilers through a reducing valve.

It is also customary where there is a surplus of exhaust steam coming from the auxiliaries or in other words more steam than can be condensed in heating the feed water in a secondary heater, to exhaust this surplus into one of the low pressure stages of the turbine or into the second receiver of a triple engine and to thus get additional work out of this waste steam.

Where steam is bled in this way a valve has to be provided to prevent steam from getting back into the turbine through the bleeder opening and causing the turbine to run away when under light load, at which time, boiler steam taken through a reducing valve would be fed into the bleeder line to supply at reduced pressure the steam needed for industrial purposes.

RANKINE EFFICIENCY AND CYLINDER EFFICIENCY

A simple calculation for a bleeder turbine with steam withdrawn at one of the higher stages and having the exhaust steam from the auxiliaries sent back into the low stage will serve to illustrate the method of getting the steam consumption.

Assume:

2000 K. W. output at switchboard.
Mechanical Efficiency of Turbine, 92%.
Generator Efficiency, 93%.
9000 lbs. steam bled out per hr. at 36 lbs. abs.
2000 lbs. exhaust steam per hr. with 1.7% moisture put back at 15 lbs absolute.

What is the steam consumption per K. W. hour with boiler pressure 177.5 lbs. ab. 97.3. Sup. and 1 lb. absolute pressure in condenser?

Making use of a temperature entropy plot or diagram, the values may be tabulated as below.

Press. ab.	Quality	Entropy	Heat Contents H	Heat of Liquid q
177.5	97.30 Sup.	1.62	1252.2	
36	.95	1.62	1120.6	230
1	.807	1.62	904.8	70
15	.983	1.73	1133.6	181.3
1	.867	1.73	966 6	70

$$\text{Rankine eff.} = \frac{H_1 - H_2}{H_1 - q_2}$$

$H_1 - H_2 = (H_1 - q_2) \times$ Rankine Eff. = heat put into work per pound in non-conducting engine.

$(H_1 - H_2) \times$ cylinder eff. = heat per pound of steam actually put into work.

$1252.3 - 1120.6 = 131.7$

$131.7 \times .45 \times .93 \times .92 = 50.7$ $\quad .45$ = cylinder eff.

$$2545 = \frac{33{,}000 \times 60}{778}$$

$\frac{2545 \times 1000}{50.7 \times 746} = 67.3$ lbs. steam per K. W. hour between 177.5 and 36 lbs. ab.

$\frac{9000}{67.3} = 133.7$ K. W. developed by the steam before it is bled.

$$1133.6 - 966.6 = 167$$
$$167 \times .50 \times .93 \times .92 = 71.4$$

A cylinder efficiency of .5 has been used because of the moisture in the steam.

$\frac{2545 \times 1.34}{71.4} = 47.76$ lbs. steam per K. W. hour between 15 lbs. and 1 lb. absolute.

$\frac{2000}{47.76} = 42.0$ K. W. recovered from exhaust put back at 15 lbs. ab.

$$1252.3 - 904.8 = 347.5$$
$$347.5 \times 63. \times .93 \times .92 = 187.3$$

$$\frac{2545 \times 1.34}{187.3} = 18.21$$

$$2000 - 133.7 - 42 = 1824.3$$
$$1824.3 \times 18.21 = 33{,}220$$

Steam bled = 9,000

Total steam to turbine from boiler = 42,220
Total steam to condenser = 33,220 + 2,000

While it may be allowable to use a ratio higher than .63, in this case .63 is conservative.

Although efficiency ratios as great as 71.8 have been obtained, in general the ratio actually realized on the commercial machine is lower.

By the addition of extra wheels in a stage or of extra stages it is possible to get the high ratios quoted, as the loss from leakage by the blades is thereby reduced, at the same time however the cost of the turbine is increased and it becomes a question as to whether or not the better economy warrants the extra expenditure due to the increased first cost.

For low pressure turbines the efficiency ratio for machines of 50 to 75 K. W. capacity is between 50 and 55 per cent.

A paper read by Mr. Francis Hodgkinson before the A. S. M. E. gives the steam consumption of Parsons Turbines under different conditions of pressure, superheat and vacuua.

As this data may be found useful the table has been reproduced here.

TABLE I.—TESTS OF WESTINGHOUSE-PARSONS STEAM TURBINES.

Size of Turbine	400 K. W.																																										
Vacuum in Exhaust	26 Inches.										27 Inches.																			28 Inches.													
Throttle Pressure Lbs. Gauge	125			140				150			150																			160													
Condition of the Steam	Dry and Saturated.			Quality = 99%.				Dry and Saturated.			Dry and Saturated.								5° Superheat.					100° Superheat.						Dry Saturated.								45° Superheat.					
Revolutions per Minute	3,600			3,600				3,600			3,600								3,600					3,600						3,600								3,600					
Turbine Number	28			35				51			47			49			55		53					37			39			55					36			52					
1 Steam pressure lbs. per gauge	125.6	124.9	130.8	142.8	144.0	144.5	138.2	151.6	151.4	149.8	153.4	153.2	153.1	152	156	155	*152	*155	140.9	148.3	154	153.5	154	149.8	160.6	152.8	155.2	147.6	155	*153.6	*154.5	*156	*155.8	*152	151.7	154.5	159	143.6	149.6	150.3	162.1	150.7	150
2 Vacuum referred to 30-inch barometer	26.0	26.02	26.03	26.0	26.0	26.0	26.0	26.06	26.06	26.06	27.04	27.11	27.06	27.15	27.2	27.25	27.01	27.01	27.0	27.0	27	27.0	27	27.01	27.0	27.0	27.05	27.0	27	28.01	27.98	27.92	28.01	28.01	28.0	28.0	28	27.78	28.03	28.0	28.01	28.02	28.02
3 Superheat, degrees Fahrenheit	2.5								2.0	4.0				3.0	5.0				7.0	6.0	4	2.0		100	103.5	95.6	97.6	104.2	103.1									45.0	44.0	42.0	45.0	41.0	45.0
4 Quality of the steam		.999	.999	.989	.980	.99	.943	1.00			1.00	1.00	.998			.997	1.00	1.00					.998							1.00	.999	1.00	.996	.986	.992	.992	1.00						
5 Revolutions per minute	3,536	3,555	3,545	3,511	3,557	3,582	3,589	3,541	3,699	3,593	3,528	3,576	3,583	3,520	3,565	3,577	3,497	3,649	3,541	3,563	3,564	3,583	3,602	3,492	3,570	3,606	3,482	3,509	3,530	3,480	3,545	3,583	3,602	3,662	3,523	3,570	3,591	3,414	3,436	3,478	3,511	3,526	3,549
6 Load in kilo-watts											438.1	298.4	211.6														411.2	311.7	219						402	292.2	198.7						
7 Load in electrical horse-power											587.3	400.0	283.6														551.1	417.9	293.7						539	391.7	266.3						
8 Load in brake horse-power	580.1	457.2	326.0	623.4	508.2	381.0	10.7	610.8	451.4	266.1				651	435	261	691	593.5	607.7	441.2	288.9	152.6	8.2	650.3	481	254.4				729	593.2	448	241	6.3				1,028.2	824.6	755.9	621.5	424.6	258.1
9 Total pounds of steam per hour	8,940	7,481	5,834	9,502	7,992	6,311	1,035	8,917	6,916	4,542	8,739	6,205	4,774	9,200	6,472	4,411	9,734	8,514	8,882	6,625	4,774	2,881	959.5	8,773	6,657	4,039.5	7,425	5,780	4,272	9,928	8,269	6,488	3,876	706	8,169	6,172	4,640	14,587	11,020	9,998	8,417	6,015	4,015
10 Pounds of steam per E. H. P. hour											14.69	15.51	16.81														13.47	13.83	14.54						15.15	15.75	17.42						
11 Pounds of steam per B. H. P. hour	15.41	16.36	17.69	15.24	15.73	16.56		14.59	15.32	17.06				14.15	14.88	16.9	14.1	14.35	14.61	15.01	16.52	18.88		13.5	13.84	15.87				13.62	13.91	14.49	16.05					14.13	13.36	13.23	13.66	14.16	15.55
12 Load in per cent. of full load	98	77	55	105	86	64	2	103	77	45	109	75	53	110	74	44	119	100	103	75	49	26	....	110	82	43	103	78	55	123	100	76	41	1	100	73	50	174	140	129	105	72	44
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43

Size of Turbine	400 K. W.												1,000 K. W.				1,250 K. W.																									
Vacuum in Exhaust	28 Inches.												27 Inches.				25 Inches.			26 Inches.			27 Inches.											27.5 Inches.						28 Inches.		
Throttle Pressure Lbs. Gauge	150												130				150			150			150											150						150		
Condition of the Steam	100° Superheat.				150° Superheat.			160° Superh.		190° Superheat.			Quality = 100%.				Quality = 98%.			Quality = 98%.			Quality = 98%.			Quality = 99%.				50° Superheat.				Dry Steam.		25° Superheat.				Quality = 98%.		
Revolutions per Minute	3,600				3,600			3,600		3,600			1,500				1,500			1,500			1,500			1,200				1,500				1,500		1,500				1,500		
Turbine Number	55*				54			55		67			15				17			17			17			32				17				31		31				17		
1 Steam pressure lbs. per gauge	*150	*150.3	*154.5	*153.3	160.6	149.4	150.2	*150.2	*153.6	148.4	147.9	149.1	132.5	132.7	134.3	139	148.7	150.5	151	150.5	150	151	147	150.4	148	147.7	146.5	148.8	149.2	149.8	149.6	149.5	151	†149.4	†146.2	146	144.3	147.8	155.1	148.8	150	151.8
2 Vacuum referred to 30-inch barometer	28.01	28.01	28.01	28.01	28.0	28.0	28.0	28.08	28.1	28.0	28.0	28.0	27.02	27.0	27.08	26.83	25.07	25.08	25.16	26.05	25.92	26.22	26.93	26.99	26.87	27.05	27.06	27.07	27.08	27.01	26.92	27.06	26.68	27.5	27.85	27.48	27.52	27.46	27.55	27.42	28.12	28.98
3 Superheat, degrees Fahrenheit	104	104	106	88	139	155.6	150	182	180	192	185	157																		50.0	51.0	49.0	54.0			28	28	28	30			
4 Quality of the steam													.999	.999	.999	.998	.98	.98	.98	.98	.98	.98	.98	.98	.98	.992	.994	.992	.991					.994	.995					.988	.975	.979
5 Revolutions per minute	3,458	3,544	3,581	3,627	3,538	3,586	3,595	3,478	3,543	3,551	3,571	3,583	1,489	1,498	1,508	1,618	1,498	1,503	1,500	1,503	1,503	1,500	1,495	1,502	1,500	1,186	1,203	1,206	1,221	1,502	1,503	1,500	1,500	1,456	1,477	1,476	1,491	1,503	1,507	1,499	1,502	1,500
6 Load in kilo-watts										428.4	303.8	197.8	1,101.7	786.7	530.7	380.1	1,506	914	310	1,619	897	306	1,629	963	254	1,630.2	1,154.5	792.1	392.5	1,475	1,253	877	302	1,510.4	1,019.1	1,557.6	1,239.8	767.9	383.4	1,545	935	262
7 Load in electrical horse-power										571.6	407.2	265.1	1,476.8	1,054.5	711.4	509.4	2,015	1,224	417	2,038	1,201	410	2,050	1,285	340	2,051.2	1,547.8	1,061.6	626.1	1,978	1,681	1,173	406	2,024.6	1,365	2,087.8	1,662	1,028.1	513.9	2,066	1,252	249.2
8 Load in brake horse-power	759	593	445	264	626	451	296.8	763	592																																	
9 Total pounds of steam per hour	9,167	7,403	5,728	3,504	7,426	5,324	3,919	8,520	6,795	7,444	5,626	4,126	21,934	16,867	12,775	10,547	32,924	23,030	11,713	32,039	21,985	10,891	31,192	21,918	9,109	30,358	23,233	18,273	10,625	27,246	24,544	19,223	9,773	28,333	20,915	28,537	23,181	16,507	10,302	3,456	19,703	7,392
10 Pounds of steam per E. H. P. hour										13.02	13.81	15.56	14.9	15.99	17.95	20.75	16.32	18.62	28.1	15.72	18.29	26.62	15.22	17.06	26.79	14.8	16.01	17.21	20.19	13.82	14.6	16.35	24.2	13.99	15.31	13.67	13.94	16.05	20.04	14.73	15.75	21.5
11 Pounds of steam per B. H. P. hour	12.06	12.5	12.87	14.48	11.86	11.87	13.2	11.17	11.46																																	
12 Load in per cent. of full load	128	100	75	45	106	76	50	129	100	106	76	50	110	79	53	38	120	73	25	121	72	24	122	77	20	123	92	63	31	118	100	70	24	120	81	125	99	61	31	124	75	21
	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85

Size of Turbine	1,250 K. W.			1,250 K. W.																																2,600 K. W. §		
Vacuum in Exhaust	28 Inches.			25 Inches.		26 Inches.		27 Inches.																28 Inches.													27.5 Inches.		
Throttle Pressure Lbs. Gauge	150			150		150		150																150													190		
Condition of Steam	140° Superheat.			Dry Saturated.		Dry Satur'd.		Dry Saturated.											75° Superheat.					Dry Saturated.					75° Superheat.				100° Superheat.				190° Superheat.		
Revolutions per Minute	1,500			1,200		1,200		1,200								1,200			1,200					1,200					1,200				1,200				1,360		
Turbine Number	17			43		43		41								43			41					41			43		41				43						
1 Steam pressure lbs. per gauge	154	149.6	143.9	*146.4	148.4	147	148.9	‡141.8	‡144.5	‡148	‡147.1	‡146.5	‡146.8	‡151.4	‡150.3	146.3	145.9	148.7	‡146.3	‡147.7	‡151	‡151.9	‡151.8	‡146.1	‡146.8	‡151	148.9	149	‡146	‡147.6	‡150.8	‡151.8	147	148.4	147.2	148.8	188	188	186
2 Vacuum referred to 30-inch barometer	28.1	28.04	28.17	25.01	25.05	26.01	26.05	26.79	26.05	27.05	27.11	27.11	27.11	27.1	27.08	27	27	26.95	27.1	27.1	27.15	27.07	27.15	28.08	28.1	28.05	28.1	28	28.1	28.1	28.05	28.05	27.95	28.02	27.97	28.02	27	27.5	27.98
3 Superheat, degrees Fahrenheit	141	139	138	2	3	1										2	2	2	76	78	77	77	77				2	2	78	77	77	78	102.3	104	102.3	102	214	180	186
4 Quality of the steam							1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	.999									1.00	1.00	1.00													
5 Revolutions per minute	1,500	1,500	1,503	1,199	1,201	1,198	1,202	1,197.4	1,200	1,201	1,196	1,197	1,199	1,201	1,201	1,199	1,199	1,202	1,201	1,205	1,209	1,213	1,201	1,197	1,201	1,198	1,200	1,204	1,199	1,204	1,214	1,217	1,203	1,202	1,203	1,199	1,360	1,360	1,360
6 Load in kilo-watts	1,512	904	306					1,988.9	1,713.5	1,489.4	1,321.5	989.5	656	342.7	197				1,293.9	986.2	664.7	333.6	191	1,364	972	334.8			1,274.2	977.6	333.2	198.4					2,995	2,518	1,945
7 Load in electrical horse-power	2,030	1,210	412					2,666	2,297.1	1,996.5	1,771.4	1,326.6	879.3	459.4	264				1,734.4	1,322	891	447.1	256	1,828.3	1,303	448.7			1,708	1,310.5	446.6	266.1					4,010	3,378	2,608
8 Load in brake horse-power				2,006.3	1,004.4	2,002.3	1,007									2,005.3	1,499.7	1,004									1,678.2	911.5					1,808	1,655.8	1,298.4	815.4			
9 Total pounds of steam per hour	26,685	17,042	8,108	28,902	16,809	28,236	16,106	40,647	33,036	28,208	25,712	20,254	15,074	9,732	7,150	27,248	21,189	15,211	23,903	19,108	14,181	9,170	6,734	25,639	19,334	9,295	21,286	13,337	22,504	18,180	8,420	6,300	23,180	21,302	17,009	11,671	44,236	39,356	30,867
10 Pounds of steam per E. H. P. hour	12.66	14.1	19.68					15.21	14.38	14.13	14.52	15.27	17.14	21.18	27.08				13.78	14.45	15.9	20.51	26.3	14.02	14.91	20.71			13.17	13.87	18.86	23.68					11.02	11.57	11.83
11 Pounds of steam per B. H. P. hour				14.39	16.73	14.10	15.99									13.59	14.13	15.18									18.49	14.63					12.82	12.86	13.09	13.70			
12 Load in per cent. of full load	121	72	24	110	55	110	55	159	137	119	106	79	53	28	16	110	82	55	104	79	53	27	15	109	78	27	87	50	102	78	27	16	99	90	71	34	115	97	75
	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124

* Test made by Mr. F. W. Dean of Dean & Main, Boston. † Tests made by a board of naval engineers. ‡ Tests witnessed and verified by engineers of the staff of Julian Kennedy, Pittsburg, Pa. § Built by the Brown-Boveri Company.

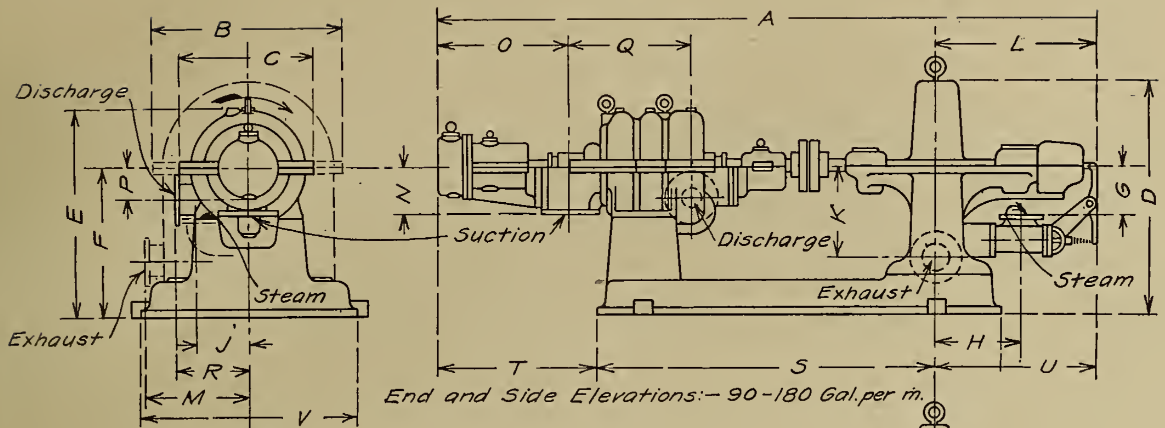
AN ARTICLE BY A. G. CHRISTIE IN VOL. 34 A. S. M. E. TRANSACTIONS CONTAINS A TABLE GIVING ECONOMY TESTS OF STEAM TURBINES. THIS TABLE GIVES IN THE COLUMN MARKED EFFICIENCY RATIO, THE COMPARISON WITH THE RANKINS EFFICIENCY

TABLE 2 ECONOMY TESTS OF HIGH PRESSURE STEAM TURBINES

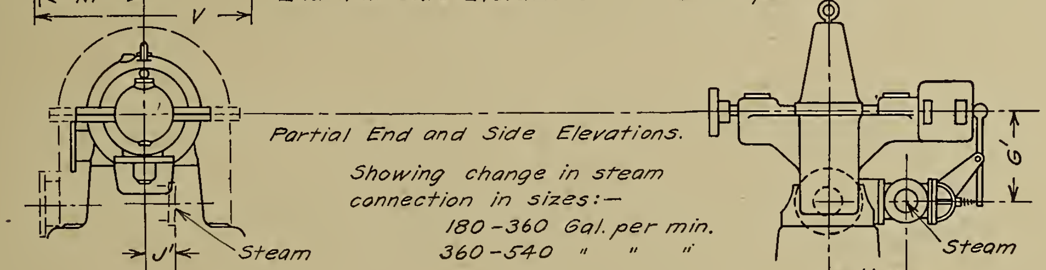
EFFICIENCY RATIOS BASED ON EFFECTIVE HORSEPOWER MARKS & DAVIS STEAM TABLES USED

Maker of Turbine	Type	Date of Test	Load-Kw.	R.p.m.	Steam Pressure Lb. Absolute	Temperature at Throttle, deg. fahr.	Vacuum referred to 29.92" Bar	Condenser Pressure, Lb. Absolute	Lb. of Steam per Kw-Hr.	B.t.u. per Kw-Hr.	Heat Utilized per Lb. of Steam	Heat Available per Lb. of Steam	Efficiency Ratio	Reference
Erste Brünner M. F. G....	Curtis-Parsons	1910	2128	1500	156.2	482	27.89	0.995	13.82	16460	247.0	343.8	71.8	Periodische Mitteilungen
Erste Brünner M. F. G....	Curtis-Parsons		6000	960	184.9	573	28.18	0.854	12.56	15570	271.5	380.7	71.3	Zeit. D.V.D. Ing., 12/10/'10
Erste Brünner M. F. G....	Curtis-Parsons	1910	7442	960	192.0	584	28.18	0.853	12.625	15705	270.2	384.4	70.3	Periodische Mitteilungen
Westinghouse Machine Co.	Curtis-Parsons	1910	9173	1800	181.7	433	27.81	1.032	14.57	16925	234.1	340.2	68.9	Trans. A.S.M.E., vol. 32
Brown Boveri & Cie.......	Curtis-Parsons		3053	1360	150.2	505	29.00	0.456	13.01	15990	262.2	385.5	68.0	Dinglers P.J., 6/17/'11
Erste Brünner M. F. G....	Curtis-Parsons	1910	1416	1260	128.2	482	27.60	1.137	15.18	18060	224.6	326.5	68.8	Periodische Mitteilungen
Brown Boveri & Cie.......	Curtis-Parsons	1911	1750	1500	176.4	586	27.08	1.392	14.23	17500	239.5	354.8	67.5	Zeit. F.D.G. Turb., 5/30/'11
Brown Boveri & Cie.......	Curtis-Parsons	1910	3764	1500	161.2	561	28.77	0.562	13.04	16290	261.5	391.4	66.8	Zeit. F.D.G. Turb., 5/30/'11
Westinghouse Machine Co.	Curtis-Parsons		9830	750	192.2	475	27.22	1.322	15.15	17790	225.2	336.0	67.0	Trans. A.S.M.E., vol. 32
Brown Boveri & Cie.......	Curtis-Parsons	1911	1495	3000	200.6	563	26.41	1.720	14.78	17880	230.7	345.5	66.8	Data from Manufacturer
Brown Boveri & Cie.......	Curtis-Parsons	1911	1271	3000	172.1	568	27.31	1.278	14.61	17880	233.5	354.3	65.9	Data from Manufacturer
Westinghouse Machine Co.	Curtis-Parsons		11466	750	191.7	484	28.07	0.910	14.45	17210	236.0	360.5	65.5	Trans. A.S.M.E., vol. 32
Erste Brünner M. F. G....	Curtis-Parsons		1250	3000	184.9	573	27.89	0.996	14.32	17680	238.2	373.1	63.9	Zeit. D.V.D. Ing., 12/10/'10
Brown Boveri & Cie.......	Curtis-Parsons	1910	3320	1500	180.9	525	29.02	0.440	13.50	16680	252.7	401.3	63.0	Zeit. F.D.G. Turb., 5/30/'11
Brown Boveri & Cie.......	Curtis-Parsons		5128	1000	171.2	565	28.52	0.726	14.35	17830	237.7	382.9	62.1	Stodola, 4th ed., p. 449
Breitfield, Danek & Co.....	Impulse-Parsons	1909	3585	896	160.7	457	28.32	0.782	16.08	19070	212.0	352.4	60.2	Zeit. D.V.D. Ing., 12/10/'10
Brown, Boveri & Cie......	Parsons	1910	6257	1210	203.7	559	29.02	0.440	11.95	14980	285.5	415.0	68.8	Official Test Report
Allis-Chalmers............	Parsons	1908	4300	1800	186.4	484	27.96	0.960	14.02	16690	243.4	355.7	68.4	Sibley Jour. of Eng., 1/11'
Brown Boveri & Cie.......	Parsons	1903	3500	1360	156.4	499	28.84	0.532	13.71	16720	248.5	378.6	65.6	Zeit. D.V.D. Ing., 12/10/'10
Brown Boveri & Cie.......	Parsons		3000	1360	165.0	625	27.02	1.420	14.75	18433	231.3	359.5	64.3	Die Turbine, 6/20/'11
C. A. Parsons & Co.......	Parsons		5164	1200	214.3	509	28.95	0.473	13.18	16140	258.7	402.3	64.3	Stodola, 4th ed., p. 439
Allis-Chalmers............	Parsons	1911	3850	1800	164.7	491	27.91	0.983	15.40	18410	221.3	348.3	63.5	Power, 1/2/'12
A. E. G..................	Curtis-Rateau	1911	6518	1220	198.7	601	29.28	0.352	11.43	14640	298.4	434.2	68.7	Official Test Report
A. E. G..................	Curtis-Rateau	1911	6565	1220	200.2	597	29.18	0.406	11.64	14848	293.0	427.7	68.5	Official Test Report
British Westinghouse......	Curtis-Rateau	1911	5066	1500	190.2	552	28.68	0.649	13.00	16100	262.4	391.5	67.0	Electrical Review, 6/23/'11
M. A. N..................	Curtis-Zoelly		3584	1500	178.3	569	27.54	1.166	13.99	17190	243.7	361.3	67.5	Data from Manufacturer
Bergmann................	Curtis-Rateau	1909	1545	1500	188.5	581	28.59	0.654	12.97	16230	263.0	396.3	66.4	Zeit. D.V.D. Ing., 12/10/'10
Bergmann................	Curtis-Rateau	1910	2477	1500	140.0	522	28.81	0.588	13.93	17135	244.8	373.4	65.6	Elec. Zeit., 4/20/'11
A. E. G..................	Curtis-Rateau	1908	4239	1500	188.3	662	29.11	0.397	11.97	15620	284.9	439.0	64.9	Stodola, 4th ed., p. 404
British Westinghouse......	Curtis-Rateau	1911	2930	1500	210.2	568	28.18	0.894	13.72	16935	248.7	383.3	64.9	Electrical Review, 4/28/'11
A. E. G..................	Curtis-Rateau	1907	3169	1500	184.7	592	29.11	0.397	12.74	16230	267.7	425.1	63.0	Trans. A.S.M.E., vol. 32
M. A. N..................	Curtis-Zoelly		2507	1500	175.5	460	27.40	1.234	16.24	19020	210.0	334.6	62.8	Data from Manufacturer
Bergmann................	Curtis-Rateau	1911	3365	1500	171.0	536	26.00	1.98	15.09	17970	234.1	381.3	68.5	Official Test Report
James Howden & Son.....	Zoelly	1909	6383	1000	202.7	520	27.33	1.269	14.305	17150	238.5	353.0	67.5	Engineer, London, 10/29/'09
M. A. N..................	Zoelly	1910	1400	3000	180.7	554	27.40	1.237	14.21	17310	240.0	356.2	67.4	Zeit. D.V.D. Ing., 12/10/'10
Escher Wyss & Co........	Zoelly	1910	2052	3000	193.9	585	28.39	0.750	13.04	16290	261.5	392.6	66.6	Zeit. F.D.G. Turb., 2/20/'11
Escher Wyss & Co........	Zoelly	1910	4189	1000	179.7	557	28.66	0.618	13.30	16520	256.5	391.3	65.5	Zeit. F.D.G. Turb., 2/20/'11
F. Ringhoffer............	Zoelly	1908	3000	1000	170.7	470	27.60	1.138	15.52	18278	219.8	339.2	64.8	Zeit. D.V.D. Ing., 12/10/'10
M. A. N..................	Zoelly	1910	1250	3000	182.1	582	28.82	0.540	13.09	16500	260.2	404.5	64.4	Zeit. D.V.D. Ing., 12/10/'10
Oerlikon................	Rateau	1911	3166	1500	213.9	663	29.25	0.367	11.44	14970	298.2	450.6	66.1	Engineering, 10/20/'10
Escher Wyss & Co........	Zoelly		5118	1000	133.7	549	27.55	1.161	15.18	18530	224.6	341.6	65.7	Dinglers P.J., 7/15/'11
Escher Wyss & Co........	Zoelly	1908	5000	1000	166.4	539	26.38	1.736	16.13	19350	211.2	330.4	63.9	Zeit. D.V.D. Ing., 12/10/'10
Escher Wyss & Co........	Zoelly		3540	1500	155.1	469	28.21	0.838	15.07	17940	226.3	349.5	64.8	Dinglers P.J., 7/15/'11
Escher Wyss & Co........	Zoelly	1910	1641	3000	221.0	672	27.91	0.985	13.08	16775	260.6	406.5	64.1	Zeit. F.D.G. Turb., 2/20/'11
Escher Wyss & Co........	Zoelly	1910	1235	3000	176.8	451	28.39	0.750	15.35	18156	222.3	357.8	62.2	Zeit. F.D.G. Turb., 2/20/'11
British Thomson-Houston.	Curtis	1911	2987	1500	154.7	505	26.75	1.557	15.96	18960	213.7	321.2	66.5	Engineering, 10/20/'11
Gen. Elec. Co............	Curtis		3464		210.0	513	28.75	0.575	13.62	16620	250.4	393.4	63.6	Trans. A.S.M.E., vol. 32
British Thomson-Houston.	Curtis	1909	2500	1500	126.5	414	28.47	0.711	15.92	18590	214.0	336.1	63.7	Zeit. D.V.D. Ing., 12/10/'10
A. E. G..................	Curtis	1906	3000	1500	191.3	590	29.05	0.427	12.79	16240	266.6	420.4	63.4	Zeit. D.V.D. Ing., 12/10/'10
A. E. G..................	Curtis	1909	2236	1500	191.6	654	29.34	0.284	11.77	15450	289.8	455.8	63.6	Zeit. D.V.D. Ing., 12/10/'10
Gen. Elec. Co............	Curtis		8880		192.5	487	28.02	0.933	15.05	17965	226.7	359.5	63.1	Trans. A.S.M.E., vol. 32
British Thomson-Houston.	Curtis	1911	1541	1500	149.7	365	27.97	0.956	17.46	19720	195.3	320.2	61.0	Engineering, 10/20/'11
Gen. Elec. Co............	Curtis		10816	750	190.0	525	29.39	0.260	12.90	16135	264.5	427.3	61.9	Trans. A.S.M.E., vol. 32
Gen. Elec. Co............	Curtis		5095		185.1	554	29.40	0.255	12.71	16090	268.4	436.0	61.6	Trans. A.S.M.E., vol. 32
British Thomson-Houston.	Curtis	1911	1221	3000	134.7	448	27.16	1.353	17.75	20690	192.2	314.0	61.2	Engineering, 10/20/'11
Gen. Elec. Co............	Curtis	1910	8775	750	194.0	451	27.95	0.956	15.95	18720	213.8	350.8	61.0	Trans. A.S.M.E., vol. 32

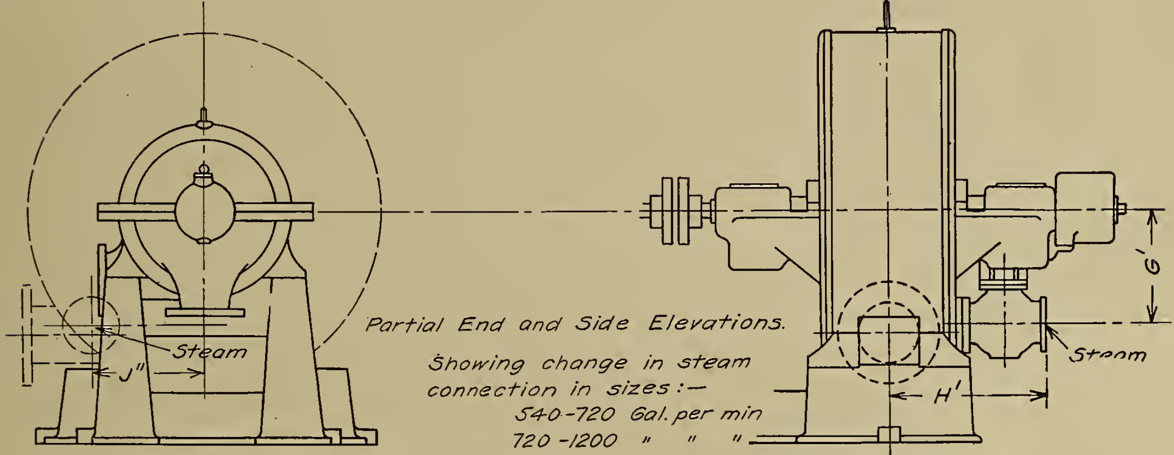
References: Zeit. D.V.D. Ing.—Zeitschrift des Vereines Deutscher Ingenieure; Zeit. F.D.G. Turb.—Zeitschrift für das Gesammte Turbinenwesen; Dinglers P.J.—Dinglers Polytechnisches Journal; Elec. Zeit.—Electrotechnische Zeitschrift.



End and Side Elevations:— 90-180 Gal. per m.



Partial End and Side Elevations.
Showing change in steam connection in sizes:—
180-360 Gal. per min.
360-540 " " "



Partial End and Side Elevations.
Showing change in steam connection in sizes:—
540-720 Gal. per min
720-1200 " " "

	Gal. per min.	90-180	180-360	360-540	540-720	720-1200
	A	8'-1 5/8"	8'-7 3/4"	8'-6 3/4"	11'-9 11/16"	12'-10 1/4"
	B	2'-5"	2'-5"	3'-1"	4'-7"	4'-7"
	C	19 1/2"			2'-8 5/8"	3'-4 1/2"
	D	2'-11 1/4"	3'-2"	3'-6 5/8"	5'-3 1/2"	4'-10"
	E	2'-6 1/2"		2'-10 3/4"	4'-2 5/16"	4'-0 7/8"
	F	22"	24 3/4	24 1/4"	3'-0"	2'-8 1/8"
Turbine	Steam dia	2"	2"	3 1/2"	3 1/2"	3 1/2"
Turbine	G	6 1/2"				
Turbine	G'		13 5/8"	14 3/8"	17 5/16"	17 3/8"
Turbine	H	11 5/8"	11 5/8"	14 7/8"	-	
Turbine	H'				24"	2'-3 1/4"
Turbine	J	8"				
Turbine	J'		4 1/2"	9"		
Turbine	J''				17 5/16"	11"
Turbine	Exhaust dia.	4"	4"	6"	9"	10"
Turbine	K	14"	14"	6 7/16"	18 1/2"	17"
Turbine	L	22"	23 3/4"	2'-2 7/16"	3'-1"	3'-1"
Turbine	M	16 1/4"	16 1/4"	18 1/2"	2'-4"	2'-6"
Pump	Suction dia.	4"	5"	5"	6"	8"
Pump	N	7 1/4"	11 3/4"	11 3/4"	16"	15 1/2"
Pump	O	19 5/8"	16 3/16"	16 3/16"	20"	21 7/8"
Pump	Discharge dia.	3"	4"	4"	5"	6"
Pump	P	4 3/4"	7 1/4"	7 1/4"	10 1/8"	10"
Pump	Q	18 9/16"	24 15/16"	24 15/16"	2'-4 15/16"	3'-5 1/8"
Pump	R	11"	12 1/2"	12 1/2"	16 1/2"	22"
	S	5'-1 7/16"	5'-8 5/16"	5'-6 5/8"	7'-10 1/8"	8'-3 3/4"
	T	23 15/16"	21 7/16"	21 7/16"	2'-1 11/16"	2'-8 5/8"
	U	12 1/4"	14"	14 11/16"	21 7/8"	21 7/8"
	V	2'-4 3/8"	2'-4 3/8"	3'-4 3/8"	4'-0 1/4"	4'-0 1/4"

BLEEDING STEAM

In many cases where efficiency is based on coal a higher plant economy may be obtained by bleeding some of the steam from one of the low pressure stages and using this steam to heat the feed water instead of passing all of the steam through the engine or turbine. If there is a considerable amount of auxiliary steam available to heat the feed water, there will in general, be no need of bleeding steam from one of the stages, as the auxiliaries will usually furnish enough exhaust to raise the temperature of the feed water. In some pumping stations, however, where the circulating water passing through the condenser does not have to be pumped by a special pump, the number of auxiliaries in use is reduced and the steam available for heating the feed water is small in amount. In such cases it may be advisable to bleed steam from one of the stages where the pressure is approximately 5 lbs. above the atmosphere. The equations for calculating efficiency where steam is bled and where steam is not bled, follow: The percentage to be bled may be anywhere from 2 to as much as 10 per cent depending upon conditions. The temperature of the feed water cannot of course, be heated to a higher temperature than that of the steam bled from the turbine.

Subscript 1 = boiler condition.

$q_1 + x_1 r_1 = H_1$

Subscript 2 = condition at lowest back pressure or pressure in condenser.

$q_2 + x_2 r_2 = H_2$

Subscript b = condition at point where bleeding takes place.

$q_f + x_b r_b = H_b$

W = total steam per H. P. hour, different in amount for Cases A and B.

B = Steam bled per H. P. hour.

$W - B$ = Steam through condenser per H. P. hour.

q_h = heat of liquid of condensed steam leaving condenser.

This water is about 7 degrees lower than the temperature corresponding to the vacuum in condenser.

q_f = heat of liquid of feed water.

Assume 60 per cent cylinder efficiency.

Case A

No Steam Bled

$2545 \div .60\,(H_1 - H_2)$ = steam per H. P. hour to be supplied by boiler.

$.60\,(H_1 - H_2)$ = heat transformed into work per pound of steam supplied.

Case B

Some Steam Bled from One of the Later Stages and Utilized to Heat the Feed Water

$$2545 \div .60 \left\{ \frac{\text{per cent through turbine to condenser} \times (H_1 - H_2)}{100} + \frac{\text{Per cent bled } (H_1 - H_b)}{100} \right\} = \text{lbs. steam per H. P. hour} = W.$$

$$.60 \left\{ \frac{\text{Per cent through}}{100} (H_1 - H_2) + \frac{\text{Per cent bled}}{100} (H_1 - H_b) \right\} = \text{B. T. U. which are transformed into work per pound of steam.}$$

$W(H_1 - q_f)$ = B. T. U. per H. P. hour to be supplied by the boiler.

$$\text{Efficiency Case } B = \frac{2{,}545}{W(H_1 - q_f)}$$

$$(W - B)(q_f - q_h) = B\left(H_1 - .6(H_1 - H_b) - q_f\right)$$

$$Wq_f = (W - B)\, q_h + B(H_b) + .40(H_1 - H_b) \times B$$

$$\text{Therefore efficiency Case B} = \frac{2545}{WH_1 - (W - B)\, q_h - BH_b - .40\, B(H_1 - H_b)}$$

$$\text{Efficiency Case A} = \frac{2545}{W(H_1 - q_h)}$$

B. T. U. put into work per pound of steam.

Case A $\quad .60(H_1 - H_2)$

Case B $\quad \frac{.60\% \text{ through}}{100}(H_1 - H_2) - \frac{.60\% \text{ bled}}{100}(H_1 - H_b)$

(1) Difference A-B $\quad .60\left\{1 - \frac{\% \text{ through}}{100}\right\}(H_1 - H_2) - \frac{.60\% \text{ bled}}{100}(H_1 - H_b)$

Case A utilizes per lb. $\frac{.60 \text{ (per cent bled)}}{100}(H_b - H_2)$ more heat units than Case B.

The heat to be supplied by the boiler per pound is

Case A = $H_1 - q_h$

Case B = $H_1 - q_f \qquad q_f = q_h \frac{\% \text{ through}}{100} + \frac{.40\% \text{ bled}}{100}(H_1 - H_b) + \frac{\% \text{ bled}}{100} H_b$

Case B = $H_1 - \frac{\% \text{ through}}{100} q_h - \frac{.40\% \text{ bled}}{100}(H_1 - H_b) - \frac{\% \text{ bled}}{100} H_b$

(2) Case A — Case B = $\left(\frac{\% \text{ through}}{100} - 1\right) q_h + \frac{.40\% \text{ bled}}{100}(H_1 - H_b) + \frac{\% \text{ bled}}{100} H_b$

$$= \frac{.40\% \text{ bled}}{100}(H_1 - H_b) - \frac{\% \text{ bled}}{100} q_h + \frac{\% \text{ bled}}{100} H_b$$

$= \frac{.40\% \text{ bled}}{100}(H_1 - H_b) + \frac{\% \text{ bled}}{100}(H_b - q_h)$ which is the difference in the heat supplied by the boiler per pound of steam

GENERAL DIMENSIONS OF ENGINES

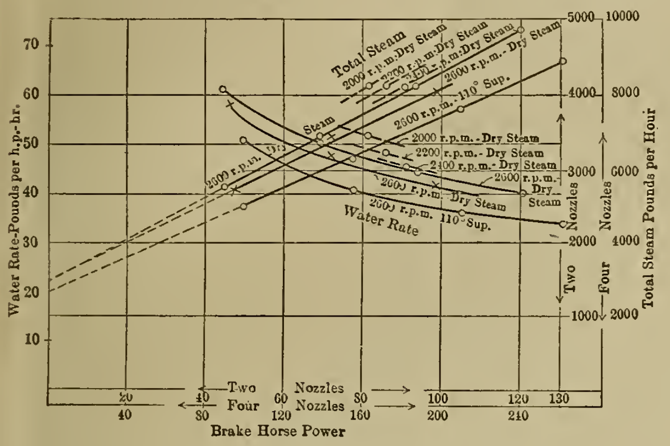
Tables of cylinder sizes, horse power and overall dimensions of a number of different engines are given on the pages following.

The engines shown are each typical of a class and have been selected with this in mind only.

In general the single cylinder engines are rated on a cut-off at about one quarter stroke.

WATER RATES OF SMALL TURBINES

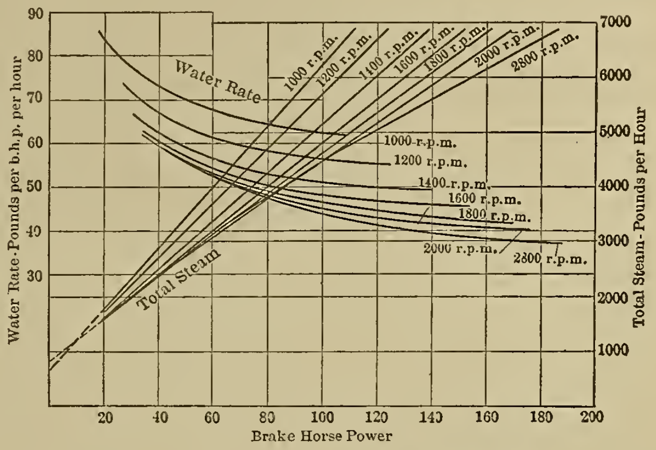
The water rates of small turbines, exhausting against atmospheric pressure, based on test are shown by the accompanying plots taken from an Article by G. A. Orrok in Vol. .31 of Transactions of A. S. M. E.



STEAM CONSUMPTION CURVES, BLISS TURBINE, NON-CONDENSING

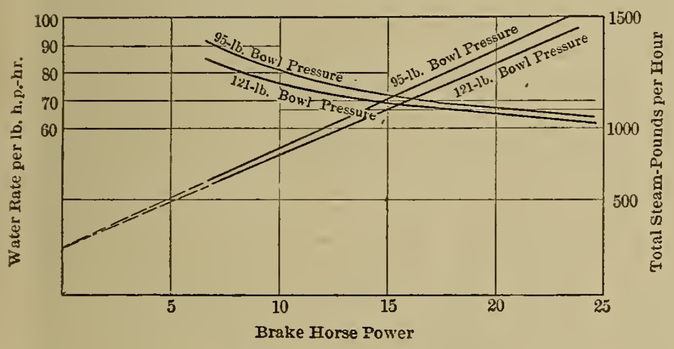
TESTED BY F. L. PRYOR AT HOBOKEN, N. J.

O = Two-nozzle, X = Four-nozzle



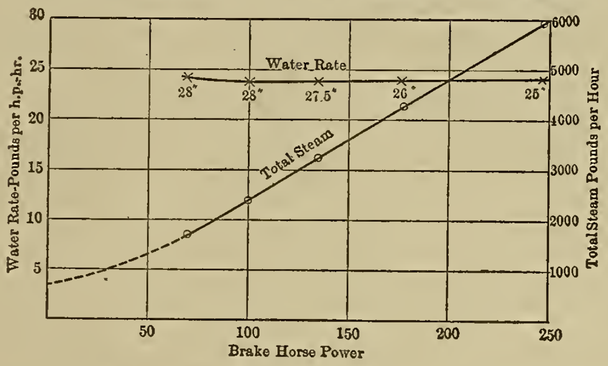
LOAD CURVES OF KERR TURBINE

24-IN. WHEEL, 8-STAGE 175-LB. GAGE PRESSURE, NON-CONDENSING



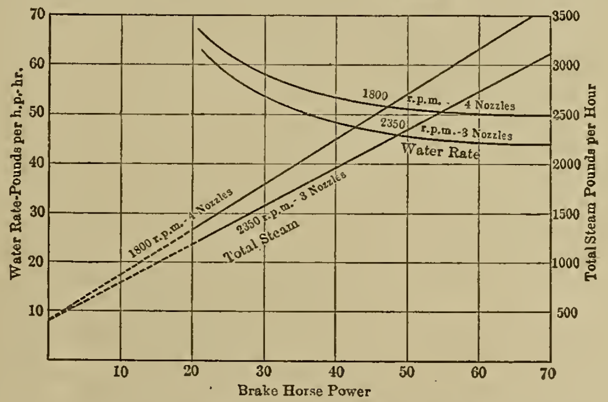
STEAM CONSUMPTION CURVES, STURTEVANT TURBINE

20-IN. WHEEL, SINGLE-STAGE, NON-CONDENSING, 2400 R.P.M.



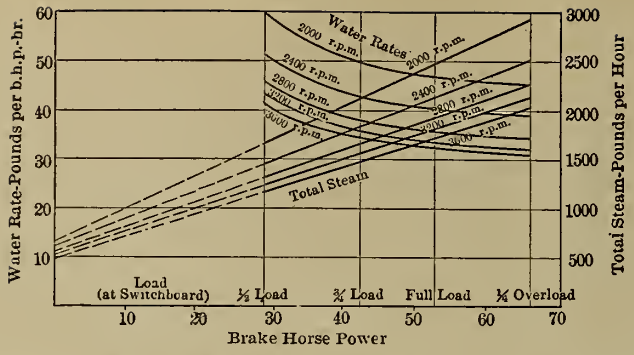
STEAM CONSUMPTION CURVES, 24-IN. KERR TURBINE

SIX-STAGE, CONDENSING, VARYING VACUUM, 70-LB. GAGE PRESSURE



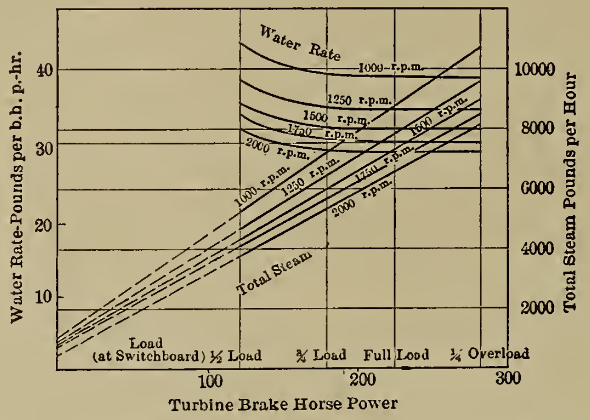
STEAM CONSUMPTION CURVES, TERRY TURBINE

24-IN. WHEEL, 150-LB. PRESSURE, NO SUPERHEAT, NON-CONDENSING. TESTED BY WESTINGHOUSE MACHINE CO., PITTSBURG, PA.



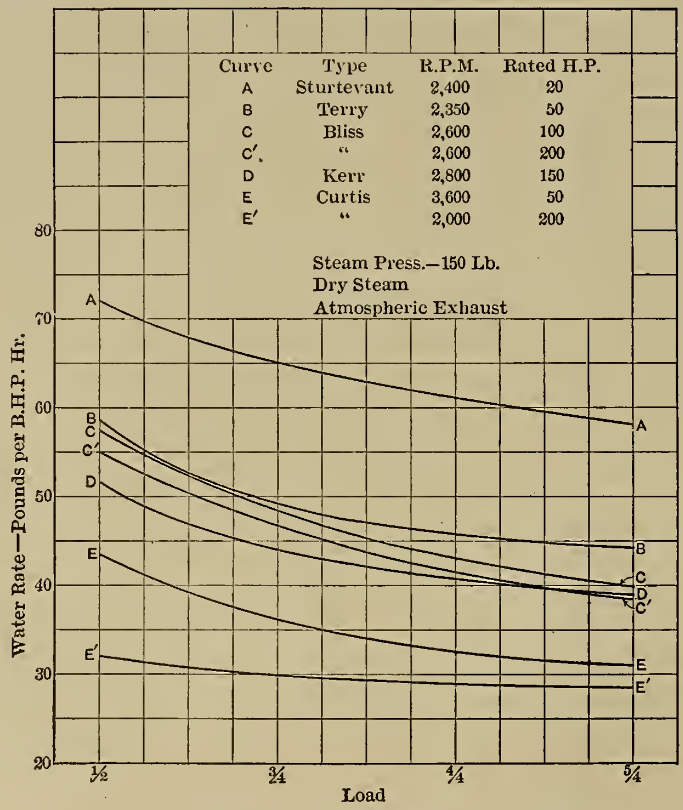
Steam Consumption Curves, 50 h.p. Curtis Turbine

ONE-PRESSURE-STAGE, THREE ROWS OF BUCKETS, 25½-IN. WHEEL, CURVES CORRECTED TO 150-LB. BOILER PRESSURE, NO SUPERHEAT, ATMOSPHERIC EXHAUST



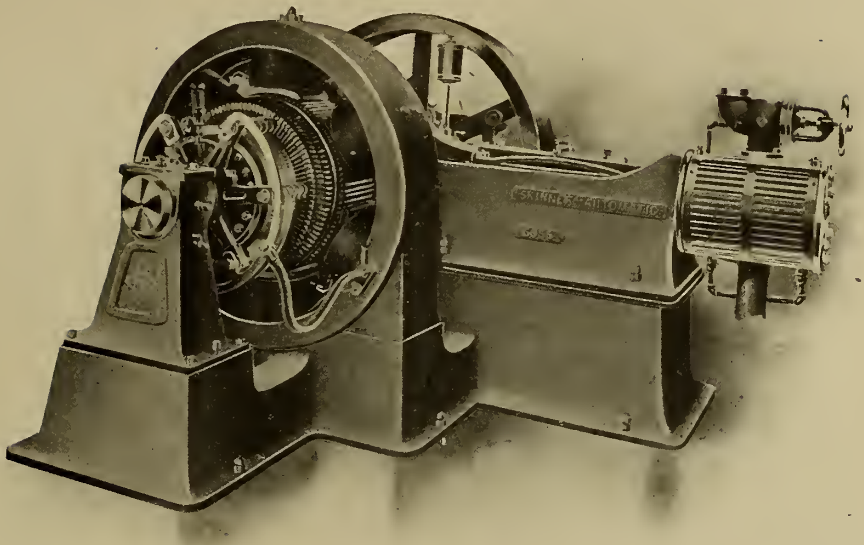
Steam Consumption Curves, 200-h.p. Curtis Turbine

THREE-STAGE, 36-IN. WHEEL, CORRECTED TO 165-LB. ABS. BOILER PRESSURE, NO SUPERHEAT, NON-CONDENSING



Economy Curves of Small Turbines

SKINNER CENTRE CRANK AUTOMATIC OILING ENGINE



SIZE OF ENGINE.	Maxim'm Rating.	Constant.	WHEELS. Diam. Inches.	WHEELS. Belt Pulley Width. Inches.	Diameter of Pipes. Steam. Inches.	Diameter of Pipes. Exhaust. Inches.	FLOOR SPACE, Belted. Length. Ft.	FLOOR SPACE, Belted. Length. Ins.	FLOOR SPACE, Belted. Width. Ft.	FLOOR SPACE, Belted. Width. Ins.	FLOOR SPACE, Direct Connected. Length. Ft.	FLOOR SPACE, Direct Connected. Length. Ins.	FLOOR SPACE, Direct Connected. Width. Ft.	FLOOR SPACE, Direct Connected. Width. Ins.	KILOWATT CAPACITY OF DYNAMO.
8 x 10	55	.00253	48	9	2½	3	7	7	4	9	7	7	6	10	20—30
9 x 10	60	.00321	48	9	3	3½	7	7	4	9	7	7	7		25—35
10 x 10	70	.00396	54	11	3½	4	8	7	4	10	8	8	7	2	35—40
11 x 10	80	.00479	54	11	3½	4	8	7	4	10	8	8	7	5	40—45
8 x 12	55	.00304	48	9	2½	3	7	8	4	10	7	8	6	10	20—30
9 x 12	60	.00385	48	9	3	3½	7	8	4	10	7	9	7	4	25—35
10 x 12	70	.00476	54	11	3½	4	8	8	4	11	8	8	7	4	35—40
11 x 12	80	.00575	54	11	3½	4	8	8	4	11	8	9	7	5	40—50
11½ x 12	80	.00629	54	11	3½	4	8	8	4	11	8	9	7	9	45—50
12 x 12	100	.00685	60	13	4	5	10		5	1	10	6	8	4	50—60
13 x 12	135	.00804	60	13	4½	6	10	1	5	2	10	7	8	6	60—75
14 x 12	135	.00932	60	13	4½	6	10	1	5	2	10	7	8	6	60—75
10 x 15	80	.00595	60	13	3½	4½	10		5	1	10	6	8	4	50
11 x 15	80	.00719	60	13	3½	4½	10		5	1	10	6	8	4	50
12 x 15	100	.00856	60	13	4	5	10		5	1	10	6	8	4	50
13 x 15	135	.01005	60	13	4½	6	10	1	5	2	10	7	8	6	60—75
14 x 15	135	.01166	60	13	4½	6	10	1	5	2	10	7	8	6	60—75
15 x 16	180	.01427	66	15	5	6	12		6	8	12	7	10	4	100
16 x 16	180	.01624	66	15	5	6	12		6	8	12	7	10	4	100
17 x 16	200	.01833	66	15	5	6	12		6	8	12	7	10	4	100—125
18 x 16	270	.02055	78	17	6	8	13	6	7	4	14	9	11	3	125—150
12 x 18	120	.01028	72	14½	4	5	12	1	6	6	12	5	10		75
14 x 18	140	.01399	72	14½	4½	6	12	1	6	6	12	5	10		75
15 x 18	180	.01606	72	16½	5	6	12	3	6	10	12	7	10	4	100
16 x 18	180	.01827	72	16½	5	6	12	3	6	10	12	7	10	4	100
17 x 18	200	.02063	72	16½	5	6	12	3	6	10	12	7	10	4	100—125
18 x 18	280	.02313	78	19	6	8	13	6	7	6	14	9	11	5	125—150
19 x 18	280	.02577	78	19	6	8	13	6	7	6	14	9	11	5	150
20 x 18	280	.02856	78	19	6	8	13	6	7	6	14	11	11	7	150—175
18 x 20	300	.0257	84	21	6	8	14	10	8	5	16	6	12	10	175—200
19 x 20	300	.02863	84	21	6	8	14	10	8	5	16	6	12	10	175—200
20 x 20	300	.03173	84	21	6	8	14	10	8	5	16	6	12	10	175—200
21 x 20	350	.03498	84	23	7	10	14	11	8	7	16	10	12	11	200
22 x 20	350	.03839	84	23	7	10	14	11	8	7	16	10	12	11	200
18 x 24	300	.03084	84	21	6	8	15	3	8	6	17	2	11	6	175—200
19 x 24	300	.03436	84	21	6	8	15	3	8	6	17	2	11	6	175—200
20 x 24	320	.03808	84	21	6	8	15	3	8	6	17	2	11	6	200
21 x 24	350	.04198	84	24	7	10	15	4	8	9	17	4	11	8	200
22 x 24	350	.04607	84	24	7	10	15	4	8	9	17	4	11	8	200

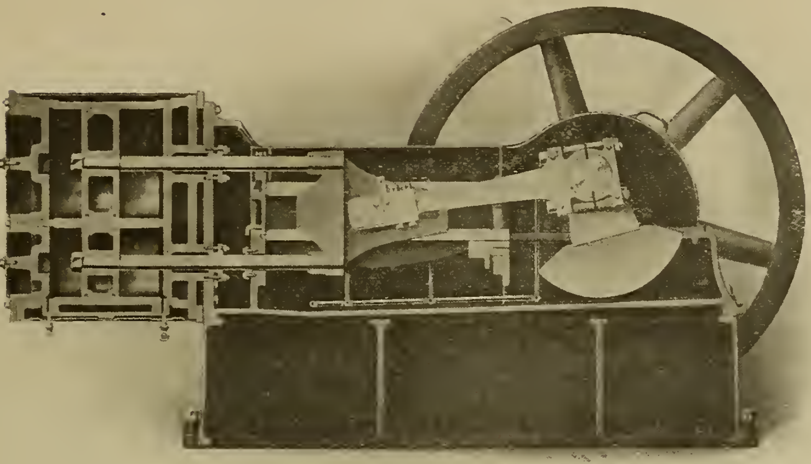
SKINNER ENGINE

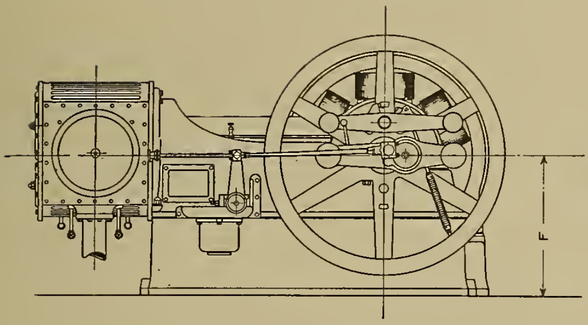
Size of Engine.	Revolutions per Minute.	Initial Pressures.					
		70	80	90	100	110	120
8 x 10	300	27	31	34	38	42	46
	325	29	33	37	41	45	50
	350	31	36	40	44	49	53
9 x 10	300	34	39	43	48	53	58
	325	37	42	47	52	57	63
	350	39	45	51	56	62	...
10 x 10	300	42	48	54	60	65	71
	325	45	52	58	64	71	...
	350	49	56	62	69	...	...
11 x 10	300	50	58	65	72	79	86
	325	55	62	70	78	86	...
	350	59	67	76	84	...	...
8 x 12	250	27	31	34	38	42	46
	275	29	34	38	42	46	50
	300	32	37	41	46	50	55
9 x 12	250	34	39	43	48	53	58
	275	37	42	48	53	58	64
	300	41	46	52	58	64	...
10 x 12	250	42	48	54	60	66	71
	275	46	52	59	66	72	...
	300	50	57	64	71	..	...
11 x 12	250	50	58	65	72	79	86
	275	55	64	71	79	87	...
	300	60	69	78	86	...	...
11½ x 12	250	55	63	71	79	87	...
	275	61	69	78	87	...	...
	300	66	76	85	...	...	...
12 x 12	250	60	69	77	86	94	103
	275	66	75	85	94	104	...
	300	72	82	93	103	...	...
18 x 16	210	150	173	194	216	237	259
	230	165	189	213	236	260	284
	250	180	206	231	257	283	...
12 x 18	175	63	72	81	90	99	108
	200	72	82	93	103	113	123
	225	81	93	104	116	127	...
14 x 18	175	86	98	110	122	135	147
	200	98	112	126	140	154	...
	225	110	126	142	157	...	...
15 x 18	175	98	113	127	141	155	169
	200	112	129	145	161	177	...
	225	127	145	163	181	...	...
16 x 18	175	112	128	144	160	176	192
	200	128	146	165	183	201	...
	225	144	165	185	206	...	...
17 x 18	175	126	144	163	181	199	216
	200	144	165	186	206	227	...
	225	162	186	209	232	...	...
18 x 18	175	142	162	182	202	223	243
	200	162	185	208	231	254	278
	225	182	208	234	260	286	...
19 x 18	175	158	180	203	226	248	271
	200	180	206	232	258	284	...
	225	203	232	261	290	...	...
20 x 18	175	175	200	225	250	275	...
	200	200	229	257	286	...	...
	225	225	257	289	...	...	...
18 x 20	160	144	165	185	206	226	247
	180	162	185	208	231	254	278
	200	180	206	231	257	283	308

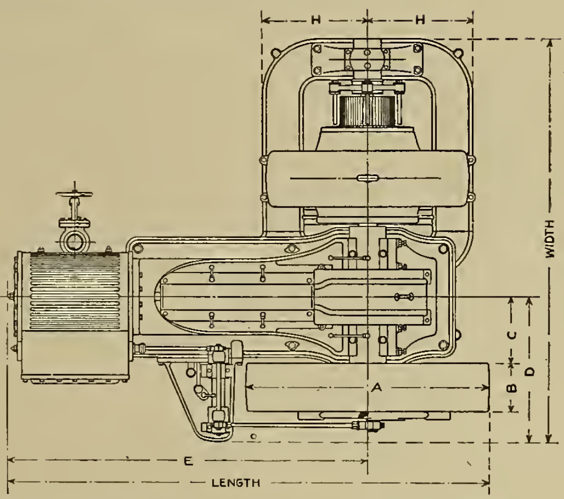
Size of Engine.	Revolutions per Minute.	Initial Pressures.					
		70	80	90	100	110	120
13 x 12	250	70	80	91	101	111	121
	275	77	89	100	111	122	133
	300	84	97	109	121	133	...
14 x 12	250	82	93	105	117	128	140
	275	90	103	115	128	141	...
	300	99	112	126	140	...	...
10 x 15	225	47	54	60	67	74	80
	250	52	60	67	74	82	...
	275	57	65	74	82	...	...
11 x 15	225	57	65	73	81	89	...
	250	63	72	81	90	...	...
	275	69	79	89	...	...	...
12 x 15	225	67	77	87	96	106	...
	250	75	86	96	107	...	...
	275	83	94	106	...	...	...
13 x 15	225	79	90	102	113	124	136
	250	88	101	113	126	138	...
	275	97	111	124	138	...	...
14 x 15	225	92	105	118	131	144	157
	250	102	117	131	146	160	...
	275	112	128	144	160	...	...
15 x 16	210	105	120	135	150	165	180
	230	115	131	148	164	181	...
	250	125	143	161	178	...	...
16 x 16	210	119	136	154	171	188	205
	230	131	149	168	187	205	...
	250	142	162	183	203	...	...
17 x 16	210	135	154	173	193	212	231
	230	148	169	190	211	232	...
	250	160	183	206	229	...	...
19 x 20	160	160	183	206	229	252	275
	180	180	206	232	258	283	309
	200	200	229	258	286	315	...
20 x 20	160	178	203	229	254	279	305
	180	200	229	257	286	314	...
	200	222	254	286	317	...	...
21 x 20	160	196	224	252	280	308	336
	180	220	252	283	315	346	...
	200	245	280	315	350	...	...
22 x 20	160	215	246	276	307	338	369
	180	242	276	311	346	380	...
	200	269	307	346	384	...	...
18 x 24	140	151	173	194	216	237	259
	150	162	185	208	231	254	278
	165	178	204	229	255	280	305
19 x 24	140	168	192	217	241	265	289
	150	180	206	232	258	284	309
	165	198	227	255	284	312	...
20 x 24	140	187	213	240	267	293	320
	150	200	229	257	286	314	...
	165	220	251	283	314	...	...
21 x 24	140	206	235	265	294	323	352
	150	220	252	283	315	346	...
	165	242	277	312	346	...	...
22 x 24	140	226	258	290	323	355	387
	150	242	276	311	346	380	...
	165	266	304	342	380	...	...

18 x 24 — 22 x 24, Side Crank only.
18 x 20 — 22 x 20, Center Crank only.
All others, Side or Center Crank.

AMERICAN BALL DUPLEX COMPOUND ENGINE FOR DIRECT CONNECTED SERVICE



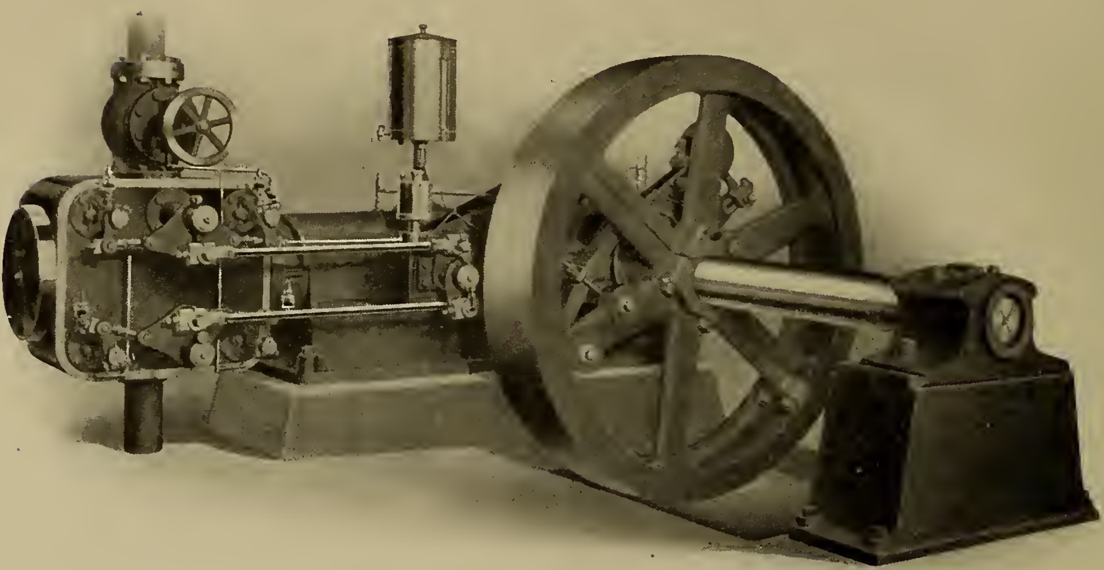




Horse-power	K. W.	Cylinder Diameters and Stroke	Revolutions per Minute	General Dimensions in Inches											Shipping Weight in Pounds	
				Floor Space		Wheels		C	D	E	F	H	Steam and Exhaust Pipes		Direct-connected Engine	Engine and Dynamo
				Length	Width	Dia. A	Width B						Steam	Exhaust		
80	50	9½&15 x 11	275 to 300	117½	94⅝	60	11	16	34⅝	87½	35½	27½	3½	5	11,600	19,800
120	75	11½&18½ x 12	260 to 290	130½	109⅛	66	13	18	39	97½	38½	28½	4	6	15,350	25,350
160	100	13 & 20 x 14	240 to 260	144¼	114¾	72	15	20½	43¼	108¼	42½	33	4½	7	21,500	33,100
200	125	14 & 22 x 16	220 to 240	157	125¼	78	17	21½	46¼	118	45	36⅝	5	8	24,500	39,300
250	150	16 & 25 x 16	210 to 230	164¼	132¾	84	19	23¾	48¾	122¼	45	42	6	9	31,700	48,200
325	200	18 & 28 x 18	190 to 210	179½	147	84	23	26	54	137½	45	49	6	10	39,500	....
400	250	20 & 32 x 18	180 to 200	184	157	90	25	28	57	139	48	54	7	12	48,000	....

NOTE—The cylinders mentioned in this table are adapted for 100 pounds steam pressure, non-condensing. For other conditions the cylinders will be varied to give best economy.

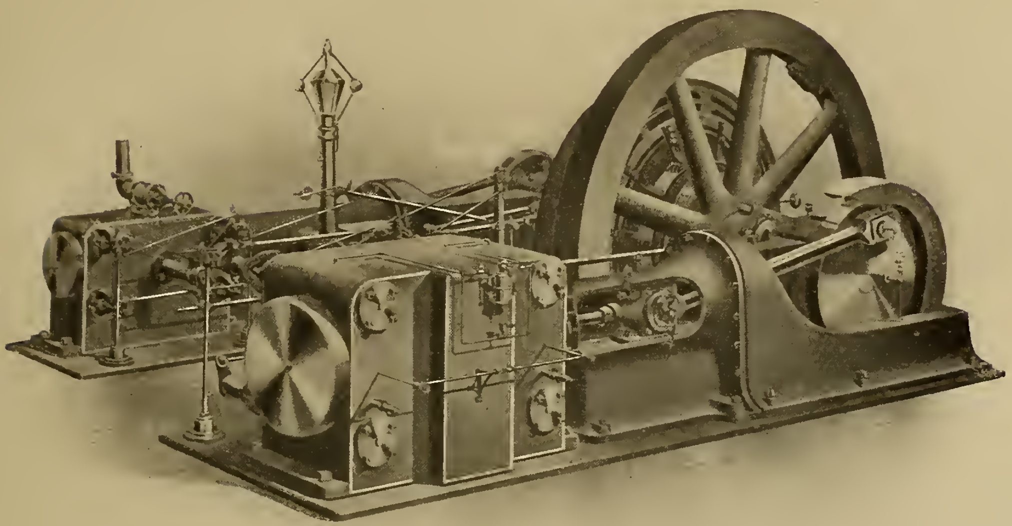
THE AJAX ENGINE, MADE BY HEWES & PHILLIPS NON RELEASING CORLISS VALVE GEAR FOR DIRECT CONNECTING UNITS



Initial Pressure in Pounds 100 — Kilowatts	125	150	Size of Engine — Inches	Revolutions	Initial Pressure in Pounds 100 — Horse-power	125	150	Diameter Steam — Inches	Diameter Exhaust — Inches	Pulley Diameter — Inches	Pulley Face — Inches	Cubic Feet in Foundation	Approximate Floor Space Belted Length Ft.	Length Ins.	Width Ft.	Width Ins.	From Center of Engine to Center of Back Bearing Ft.	Ins.	From Center of Crank-shaft to end of Cylinder Ft.	Ins.	From Center of Engine to Floor Ft.	Ins.	Constant Based on 1 Pound M. E. P. 1 Rev.
58	72	88	12 x 15	225	86	108	132	4½	6	72	16	252	11	7	6	0	4	6	8	0		21	.0085
66	85	104	13 x 15	225	100	127	156	5	6	72	16	260	11	7	6	0	4	6	8	0		21	.0100
73	91	112	13½ x 15	225	110	137	168	5	6	72	16	260	11	7	6	0	4	6	8	3		21	.0108
79	95	120	14 x 15	225	118	147	181	5	6	72	16	270	11	8	6	5	5	0	8	3		21	.0116
83	105	129	14½ x 15	225	125	157	193	5	6	72	16	270	11	8	6	5	5	0	8	5		21	.0124
90	113	140	15 x 15	225	135	170	210	6	7	72	16	280	11	10	6	7	5	1	8	5		21	.0134
100	129	160	16 x 15	225	150	193	237	6	7	72	16	280	11	10	6	7	5	1	8	8		21	.0152
83	105	129	14 x 16	225	125	157	193	6	7	72	16	270	11	8	6	5	5	0	9	0		21	.0124
90	112	138	14½ x 16	225	135	169	207	6	7	72	16	270	11	8	6	5	5	0	9	0		21	.0133
96	120	150	15 x 16	225	145	181	223	6	7	72	16	290	11	10	6	7	5	1	9	2		21	.0143
106	136	167	16 x 16	225	160	204	251	6	7	72	18	290	11	10	6	9	5	2	9	2		21	.0161
123	154	190	17 x 16	225	185	231	286	6	7	72	18	290	11	10	6	9	5	2	9	4		21	0183
113	143	173	16 x 18	210	170	215	265	6	7	78	20	300	13	5	7	7	6	0	9	6		21	.0182
130	162	200	17 x 18	210	195	244	300	6	7	78	22	320	13	5	7	9	6	1	9	6		21	0206
143	181	223	18 x 18	210	215	272	335	6	7	78	24	330	13	5	7	11	6	3	9	8	2	1	.0230
160	202	269	19 x 18	210	240	304	404	7	8	78	26	360	13	5	8	10	7	0	9	8	2	1	.0257
178	225	276	20 x 18	210	268	338	415	7	8	78	28	420	13	8	9	0	7	3	9	10	2	1	.0285
130	162	200	17 x 19	200	195	245	301	6	7	84	24	430	13	11	7	11	6	3	10	0	2	1	.0217
150	182	225	18 x 19	200	220	274	337	6	7	84	25	440	13	11	8	0	6	3	10	0	2	1	.0243
160	204	251	19 x 19	200	240	306	376	7	8	84	26	450	13	11	8	10	7	0	10	2	2	1	.0271
180	226	278	20 x 19	200	270	340	418	7	8	84	26	460	13	11	8	10	7	0	10	6	2	1	.0301
153	192	236	18 x 20	200	230	289	355	6	7	84	26	470	14	10	8	2	6	5	10	8	2	1	.0256
170	215	264	19 x 20	200	255	322	396	6	7	84	28	480	14	10	9	0	7	3	10	8	2	1	.0285
190	238	293	20 x 20	200	285	358	440	7	8	84	30	500	14	10	9	2	7	4	10	10	2	1	.0317
206	262	323	21 x 20	200	310	394	485	7	8	84	32	500	14	10	9	2	7	4	11	0	2	1	.0349

HORSE-POWER.—In the computation of the power of an engine, the prime factors are area of cylinder, pressure of steam, piston speed, and point at which steam is cut off. Our calculations of horse-power, as indicated in the above table, are based upon an initial steam pressure of 100, 125 and 150 pounds per square inch, valve gear cutting off at ¼ stroke, piston speed varying from 562 feet for the smallest up to 666 for the largest size. These conditions can be changed, and by increasing one or all, the power of an engine is increased in like proportion.

HEWES & PHILLIPS HEAVY DUTY
CROSS COMPOUND CORLISS ENGINE — TANGYE TYPE



Dimensions of Cylinder		Band Wheels			Horse-power 80 Lbs. Initial Pressure ¼ Cut-off		Horse-power 90 Lbs. Initial Pressure ¼ Cut-off		Horse-power 100 Lbs. Initial Pressure ¼ Cut-off		Size of Quadrangle within which Engine including Fly-wheel will stand				Length of Crank-shaft from Outside of Main Bearings		Distance from Center of Crankshaft to End of Cylinder		Height from Base-plate to Center of Crankshaft		Horse-power Constant Based on Pound M. E. P. 1 Rev.
Bore in Inches	Stroke in Inches	Diameter in Feet	Face in Inches	Weight in Pounds	Revs. per Minute	Horse-power	Revs. per Minute	Horse-power	Revs. per Minute	Horse-power	Length Ft.	Length Ins.	Width Ft.	Width Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	
10	24	6	12	4000	125	50	125	55	125	62	13	1	5	11	5	$2\frac{3}{16}$	10	1	1	11	.0094
12	24	7	14	5000	125	75	125	84	125	93	14	11	6	9	5	3	10	11	1	11	.0137
12	30	8	14	6000	120	85	120	94	120	104	16	11	6	9	5	$2\frac{13}{16}$	12	11	1	11	.0171
14	30	8	18	7000	120	115	120	125	120	137	17	7	7	7	5	$10\frac{7}{8}$	13	1	2	1	.0230
14	36	9	18	8000	110	126	110	143	110	160	19	7	7	7	5	$10\frac{7}{8}$	15	1	2	1	.0276
16	30	10	20	9000	120	151	120	170	120	190	18	5	8	8	6	6	13	5	2	3	.0301
16	36	10	24	10000	110	166	110	190	110	213	20	5	8	8	6	6	15	5	2	3	.0361
16	42	12	24	10600	100	177	100	200	100	226	23	5	8	8	6	6	17	5	2	3	.0421
18	36	12	26	12000	110	210	110	240	110	270	21	6	9	5	8	$3\frac{1}{16}$	15	6	2	5	.0457
18	42	14	28	14000	100	223	100	255	100	287	24	6	9	5	8	$3\frac{1}{16}$	17	6	2	5	.0533
20	36	12	28	14000	110	236	110	270	110	305	22	11	10	3	8	$8\frac{1}{2}$	15	11	2	6	.0564
20	42	14	30	17000	100	275	100	315	100	355	24	11	10	3	8	$8\frac{1}{2}$	17	11	2	6	.0658
20	48	16	34	19000	90	284	90	325	90	365	27	11	10	3	8	$8\frac{1}{2}$	19	11	2	6	.0753
22	42	16	36	21000	100	334	100	382	100	422	26	2	11	1	10	3	18	2	2	9	.0797
22	48	16	38	23000	90	344	90	393	90	442	28	2	11	1	10	3	20	2	2	9	.0911
22	54	16	40	25000	80	344	80	395	80	442	30	2	11	1	10	3	22	2	2	9	.1024
24	42	16	40	22000	100	398	100	454	100	510	28	8	12	0	11	3	20	8	2	11	.0948
24	48	16	40	24000	90	408	90	468	90	527	30	8	12	0	11	3	22	8	2	11	.1084
24	54	16	44	26000	80	410	80	468	80	526	32	8	12	0	11	3	24	8	2	11	.1219
26	48	16	44	30000	90	480	90	548	90	617							21	5	2	9	.1272
26	54	18	46	32000	80	480	80	549	80	618							23	5	2	9	.1431
26	60	18	48	34000	75	501	75	572	75	644							25	5	2	9	.1591
28	48	18	48	32000	90	563	90	645	90	726							21	9	2	10	.1477
28	54	18	52	34000	80	563	80	645	80	727							23	9	2	10	.1662
28	60	18	54	36000	75	587	75	672	75	757							25	9	2	10	.1846
30	48	18	56	34000	90	646	90	739	90	833	Shafts as desired						22	2	2	10	.1694
30	54	18	60	38000	80	646	80	740	80	834							24	2	2	10	.1906
30	60	18	64	40000	75	673	75	771	75	868							26	2	2	10	.2118
32	48	18	58	36000	90	736	90	841	90	948							22	7	2	10	.1928
32	54	20	62	39000	80	734	80	841	80	947							24	7	2	10	.2166
32	60	20	66	43000	75	766	75	877	75	988							26	7	2	10	.2410
34	54	20	78	60000	80	840	80	961	80	1083							24	11	2	11	.2477
34	60	20	78	60000	75	865	75	990	75	1115							26	11	2	11	.2720

HORSE-POWER.— In the computation of the power of an engine, the prime factors are area of cylinder, pressure of steam, piston speed, and point at which steam is cut off. Our calculations of horse-power, as indicated in the above table, are based upon an initial steam pressure of 80, 90 and 100 pounds per square inch, valve gear cutting off at ¼ stroke, piston speed varying from 500 feet for the smallest up to 750 for the largest size. These conditions can be changed, and by increasing one or all, the power of an engine is increased in like proportion.

CONDENSERS AND ACCESSORIES

The pressure in a condenser is always higher than the pressure due to the temperature of the steam. The difference between the pressure in the condenser and the pressure due to the temperature of the steam, gives the pressure exerted by the air in the condenser. The air comes in part from the feed water entering the boiler, in part from the circulating water, in the case of the jet condensers, and in part from leakages of air into the condensing outfit. Water at atmospheric conditions, contains from 2 to 5 per cent of air by volume. It is evident that the leakage of air into the condensers may be much or little according to the care with which the condenser outfit was installed.

In general, a wet air pump handling the air and circulating water for a jet condenser, when running at a piston speed of 50 feet per minute, should displace in one hour from three to three and one-half times the volume of circulating water used per hour. The wet pump for a surface condenser handling both condensed steam and air, should displace per hour, 35 times the volume of water coming out of the condenser per hour as condensate. The displacement of 35 volumes is generally considered about right for a vacuum of 28 inches. If higher vacuua are carried, the figure should be increased, running up to perhaps 40.

The vacuum in a condenser is generally measured either by the difference in level of mercury in a U-tube, or by the height of a column of mercury in a single tube, this height being measured above the surface in an open vessel filled with mercury, into which the tube extends. The difference in level thus read, should be corrected for temperature, if the percentage of the perfect vacuum is to be obtained by comparison with a barometric reading reduced to 32 degrees and to sea level. This correction may be made with sufficient accuracy as follows:—

$$\text{The corrected height} = \text{observed height } (1 - .0001\ (t - 32)\ ).$$

The amount of cooling water required for the condensation of a pound of steam is commonly figured, assuming a 20 degree increase in temperature with cold cooling water at 70 degrees. The heat to be abstracted from each pound of steam which has passed from the throttle through the condenser may be found by subtracting from the heat brought in by a pound of boiler steam, the heat transformed into work by a pound of this steam and the heat of the liquid condensate leaving the condenser.

If steam is bled from or supplied to any stages or receivers of a turbine or engine, the amount of heat to be abstracted by the condenser may be calculated by the same process. Proper allowance of course must be made for the steam which is taken out before reaching the condenser and for the heat in any steam put back into the condenser and for the heat, from such steam, which is transformed into work. See in this connection the discussion of the bleeder type turbine under the general heading of Cylinder Efficiency and Rankine Efficiency.

SURFACE CONDENSERS

(1) The rate of heat transmission through a tube is nearly directly proportional to the mean difference in temperature between the liquid on the inside and the vapor on the outside of the tube.

(2) The rate of heat transmission is proportional to the square root of the velocity of the vapor normal to the line of tubes.

(3) The rate of heat transmission is proportional to the cube root of the velocity of the water in the tubes.

An article by Mr. Orrok in "Power" of August 11, 1908, gives a summary of the various tests made on the transmission of heat through condenser tubes. A smooth curve representing the mean of the various experimental results was drawn by Mr. Orrok, who proposed the following formula for U the heat transmission per sq. ft. per hour per degree difference of temperature inside and outside of the tube:—

$$U = 17\sqrt{V_s}\ \sqrt[3]{.023 + V_w}$$

V_s = velocity of steam by the tube generally taken as 625 ft. p. sec.
V_w = velocity of water in tube in ft. per sec.

Values read from the curve give —

Vel. of water in tubes in ft. per second.	U	Vel. of water in tubes in ft. per second.	U
.5	350	4	675
1	430	5	725
2	545	6	775
3	620	7	815

Experiments by Mr. E. Josse have shown much higher values for tubes which were drained in such a way that the steam condensed on the upper rows did not trickle down over the lower rows but was drained to the shell, thus keeping the efficiency of the lower tubes equal to that of the upper tubes. For such tubes it appeared that the constant 17 in the preceding formula for U should be made 20 or 25.

Later on Mr. Crrok did a considerable amount of experimental work on this subject and as a result of his more recent work he developed the following formula and conclusions which are copied from Transactions A. S. M. E., 1910.

(a) The heat transferred from condensing steam surrounding a metallic tube to cold water flowing through the tube is proportional to the seven-eighths power of the mean temperature difference of the water and steam temperatures. This is equivalent to the statement that the coefficient of heat transfer, U, is inversely proportional to the eighth root of the mean temperature difference.

(b) The coefficient of heat transmission, U, is approximately proportional to the square root of the velocity of the cooling water.

(c) The coefficient U is independent of the vacuum and of the velocity of the steam among the tubes or in the condenser passages. It may be proportional to the square root of the velocity normal to the tubes, but in all common cases this velocity does not vary more than a tenth part.

(d) The effect of air on the heat transferred is very marked indeed, particularly at high vacuua, and most of this air is due to leakage through the walls and joints of the apparatus. The effect of the presence of air in reducing the value of U is as follows:

$$U = c\left(\frac{P_s}{P_t}\right)^5$$

where P_s is the partial pressure due to the steam and P_t is the total steam and air pressure.

(e) Taking the heat transfer of the copper tube as 1.00 under similar conditions the transfer for other materials is approximately as follows:— copper, 1.00, Admirality 0.93, aluminum lined 0.97, Admiralty oxidized (black) 0.92, aluminum-bronze 0.87, cupro-nickel 0.80, tin 0.79, Admiralty lead-lined 0.79, zinc 0.75, Monel metal 0.74, Shelby steel 0.63, old Admiralty (badly corroded) 0.55, Admiralty vulcanized inside 0.47, glass 0.25, Admiralty vulcanized both sides 0.17. This coefficient (due to the material of the tube) will be designated by μ. Corrosion, oxidation, vulcanizing, pitting, etc., have also a marked effect in reducing the transfer. This reduction, best shown by the Admiralty tube which gave $\mu = 0.55$, may reduce the transfer at least 50 per cent.

(f) The foregoing conclusions may be expressed mathematically as follows:

$$U = K\frac{C\,\varphi^5\,\mu\,\sqrt{V_w}}{\theta^{\frac{1}{8}}}$$

where C = the cleanliness coefficient varying from 1.00 to 0.5
μ = material coefficient varying from 1.00 to 0.17

φ = the steam richness ratio $\frac{P_s}{P_t}$ varying from 1.00 to 0

V_w = the water velocity in ft. per sec.
θ = the mean temperature difference.
K = a constant, probably about 630.

The effect of the length of tube, or rather length of water travel, has not been considered and the design of the condenser must be such that there is a free steam passage to every tube.

(g) This expression for U is cumbersome to use and for modern turbine condenser work certain conditions may be taken as well settled. The guaranteed vacuum is usually 28 ins. The entrance circulating water is usually 70 deg. and a 20-deg. temperature rise is considered economical. Under these conditions θ =18.3 and $\theta^{\frac{1}{8}}$ = 1.44. θ calculated on the geometrical curve is 18.2. For these cases it will be nearly as accurate and much simpler to calculate θ by the logarithmic method, neglecting θ in the denominator and using 435 or $\frac{630}{1.44}$ for K^1. The expression will then be

$$U = K'C\,\varphi^5\,\mu\,\sqrt{V_w}$$

(h) The above equation agrees well with the results of a number of tests on full sized condensers under varying conditions. There appears to have been no attempt to determine the amount of air handled by the air pump in these cases, but the amounts of air indicated by the formula are such as agree with the pressures and temperatures taken.

Later work by Mr. Orrok, led him to suggest that the term $\varphi^2 = \left(\frac{P_s}{P_t}\right)^2$ be substituted for φ^5 in the expression for U.

The value 525 has been commonly used as the B. T. U. per sq. ft. per hour per degree difference in temperature.

The modern surface condenser used for steam turbine work is designed to maintain a temperature in the hot well as near as possible to the temperature corresponding to the vacuum.

The mean temperature difference is often taken as $t_s - \frac{t_h + t_c}{2}$ where t_s = the temperature of the steam; t_h = the temperature of the hot condensing water and t_c the temperature of the cold condensing water.

The true mean temperature difference $\theta = \dfrac{t_h - t_c}{\log_e \dfrac{t_s - t_h}{t_s - t_c}}$

If t = any momentary temperature; W the weight of injection water per hour; V the B. T. U. per hour per square foot of surface per degree difference in temperature, and A the condensing surface in square feet.

$$U\,dA\,(t_s - t_c) = W\,dt \qquad A = \frac{W}{U}\int_{t_h}^{t_c} \frac{dt}{t_s - t_a} = \frac{W}{U}\log_e \frac{t_s - t_h}{t_s - t_c}$$

$$\theta\,U\,A = W\,(t_h - t_c) \text{ whence } \theta = \frac{t_h - t_c}{\log_e \dfrac{t_s - t_h}{t_s - t_c}}$$

Illustration of method of calculating surface needed in a condenser. Condenser to handle 15,000 lbs. steam per hour, the steam containing 6 per cent of moisture: Vacuun 28″; Barometer 30″; cold water 70°; hot water 90°; condensate 5 degrees below temperature of steam. The difference between the pressure in the condenser and that corresponding to the temperature of the steam is ¼″ of mercury in this case. Velocity of injection water through tubes 7 feet per second. Required total surface $U = 435 \times C \times \varphi^2 \times \mu \sqrt{V_w}$; using .75 for C and $\frac{30 - 28 - .25}{30} = .875$ for φ; .7 for μ this becomes $435 \times .75 \times .76 \times .7 \times 2.64 = 458$. $\theta = 18.3$ see item (g) in quotation from Orrok's paper. $458 \times 18.3 = 8391$. B. T. U. per hour per square foot of surface.

The heat to be abstracted is $15000\,(.94\,r + q - 59.8) = 13{,}843{,}500$ B. T. U.; r and q being taken at $1.75 \times .491 = .86$ lbs. absolute. $13{,}843{,}500 \div 8{,}391 = 1650$ square feet, the surface needed.

In general from 1.2 to 2.5 square feet of surface are allowed per K. W. for large units, the amount of surface increasing to 4 square feet per K. W. for small units.

WESTINGHOUSE-LEBLANC SURFACE CONDENSERS

An Abstract from the May, 1914, *Bulletin of the Westinghouse Machine Company.*

The principles governing the design of jet condensers, in which there is an intimate mixture of the steam and circulating water, are simple and well known, but in surface condensers where the heat of the exhaust steam is transmitted to the cooling water through metal tubes, the problem is more complex.

In designing a surface condenser, the amount of steam to be condensed, the vacuum desired and the temperature and amount of circulating water available, are determinate. Not only do these bear a close inter-relation, but they have a marked effect on the other details of design.

Knowing the total number of heat units to be taken from the steam and the amount of heat (depending upon its temperature rise) which each pound of circulating water will absorb, the amount of surface necessary to transmit the heat may be determined. This calculation will involve a consideration of the following: (1) The velocity of the circulating water, (2) the material used for tubes and their arrangement, (3) the mean temperature difference between the steam and water. and (4) the amount of air on the steam side of the tubes.

(1) Careful investigations show that the heat transfer varies approximately as the square root of the velocity of the cooling water in the condenser tubes. Therefore, the higher the velocity of the water, the greater the heat transfer, but due account must be taken of the greater power required for high velocities. In general, the velocity should be such as will result in tumultous rather than smooth and stratified flow, thereby bringing each particle of water into contact with the surface of the tubes.

(2) Different materials may be used for the tubes depending on the nature of the circulating water. Copper alloys are more generally used than other materials. In the arrangement of the tubes, it is quite important that restricted passages be avoided so the steam may pass freely from one side of the condenser to the other, thereby avoiding undue pressure drop or loss in vacuum.

(3) The amount of heat which will pass through the tube wall is proportional to the mean temperature difference which is determined by the expression —

$$\frac{t_h - t_c}{\text{Log}_e \dfrac{t_s - t_h}{t_s - t_c}}$$

when t_s is the temperature of the steam, t_c and t_h are the temperatures of the intake and discharge water respectively. For ordinary conditions, it is sufficiently accurate to use the arithmetical mean as calculated from the expression —

$$t_s - \frac{t_h + t_c}{2}$$

(4) The most important factor affecting heat transfer is the presence of air on the steam side of the tubes. Some of this air is carried into the condenser with the steam but this quantity is so small as to be almost negligible. The greater portion enters by leakage at valves and joints and by infiltration through the cast iron connections and the condenser shell.

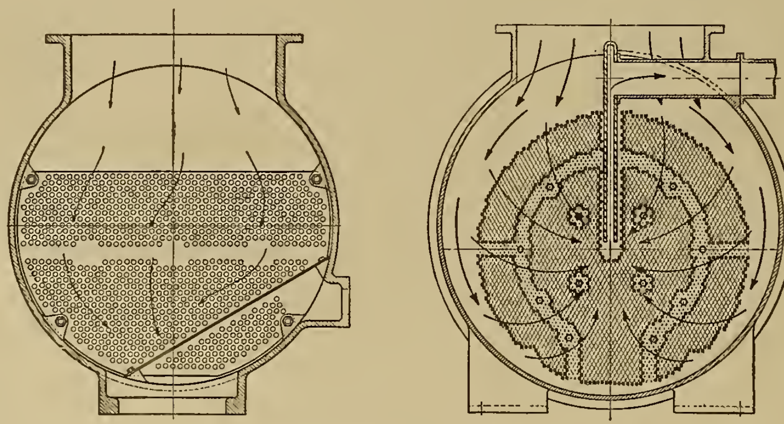
Under the low pressure conditions existing in a condenser the density of air is greater than steam. So if any appreciable amount of air is present it will collect in the bottom of the condenser and "drown" or "blanket" the lower tubes, thereby preventing the steam from coming into proper contact with them. It is therefore necessary, if the best results are to be obtained, that the air be removed continuously and completely from the steam space.

Any air in the steam space will have a finite pressure and the total pressure would be due partly to steam and partly to air pressure. As may be seen by reference to any "Steam Tables" the vapor at a given pressure has a definite temperature — the lower the pressure, the lower the temperature. It is obvious that if the air pressure is high, the steam pressure is low with a correspondingly low temperature.

A concrete case in tabular form will make this relationship clear. In some condensers the difference in temperature between the upper and lower portions of the steam space may be 10 or 15° F., while in others not more than 1 or 2° F. Assuming the total absolute pressure in the top of the condenser to be 0.975 pounds per square inch, (vacuum 28.01″) and temperatures of 85, 90 95, and 100° F. in the lower portion of the steam space with no pressure drop in passing through the condenser, the resulting air and steam pressures are as follows:

Temperatures in bottom of Condenser	85°	90°	95°	100°
Total pressure lbs. per square inch	0.975	0.975	0.975	0.975
Steam pressure corresponding to assumed temperature	0.594	0.696	0.813	0.946
Air pressure	0.381	0.279	0.162	0.029

From this tabulation it will be seen that with a vacuum of 28.01″ if the air pressure is 0.381 the maximum temperature of the steam in the lower portion of the condenser is 85° F., when 0.279



Cross-section showing arrangement of Tubes

pounds 90° F., etc., showing very clearly how the pressure of air lowers the steam temperature and consequently, the "heat head" between the steam and cooling water. It is only by removing the air to the lowest possible amount, that the maximum "heat head" and consequent rate of heat transfer may be secured.

Another loss arising from the presence of air is due to the fact that the temperature of the condensate must be raised a greater amount the higher the air pressure.

The condenser shell which is usually circular in form, is made of exceedingly close grained cast rion, the location of the water and steam connections being determined by local conditions.

In the smaller sizes, say up to 10,000 square feet, the shell and nest of tubes are concentric, as shown at the left in the cross section on the page preceeding this.

The pitch and arrangement of the tubes is such that the pressure drop of the steam in passing from one side to the other is negligible.

In large condensers, owing to the distance the steam has to travel, special care is necessary to prevent undue resistance and consequent loss in vacuum. At the right in this same cut is a sectional view of a large condenser. The nest of tubes is placed non-concentric to the condenser shell, so that steam enters around the whole periphery. Such an arrangement practically doubles the area for the admission of the steam, and so results in a velocity only one half of that in other types. The air offtake consists of two parallel plates extending the entire length of the condenser, thus reducing the distance the air has to travel to one half of that in the older types of condensers.

As all condensate must fall through the surrounding envelope of live steam, its temperature will be practically the same as that of the entering steam.

The advantages of this arrangement may be summarized as follows:

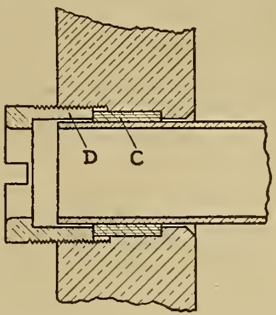
First: Non-concentric arrangement of tubes gives a steam velocity only one half of that in the ordinary type.

Second: Radial flow reduces the length of the steam path through the tubes to one half of that ordinarily existing.

Third: Highest possible temperature of condensate.

How well this design fulfills its purpose, is shown by numerous tests made on large condensers where the temperature of the condensate was found to be within one or two degrees of that of the incoming steam, and the difference in pressure between the air pump offtake and the top of the condenser not more than 0.1″ mercury.

The condenser tubes used are of different standard materials depending on the character of the cooling water. Muntz metal is generally used for both the tubes and tube sheets. To prevent sagging, long tubes are supported between the ends, the number of supports depending on the length. The method of packing each end of the tubes is shown by the cut. C is a fibre packing held in place and expanded by bronze nut D. The fibre expands when wet and makes a tight joint which is, however, easily removable in case it is necessary to replace a tube.



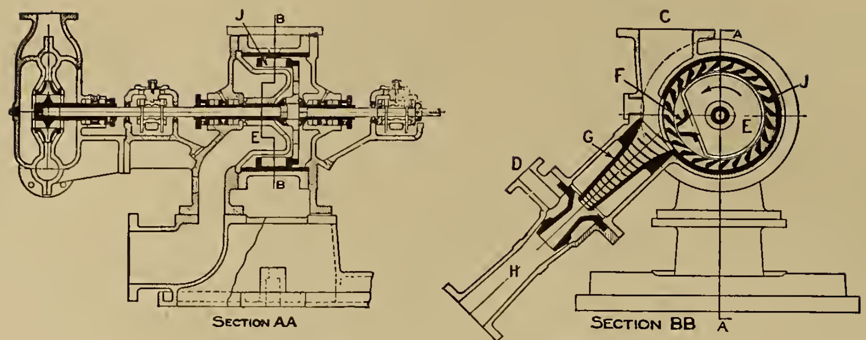
—Tube Packing

In view of the importance of completely scavenging the condenser of air, it is obvious that the air pump must be capable of handling it at extremely low pressures from which it must be compressed to that of the atmosphere. The fact that the volumetric efficiency of the Westinghouse-Leblanc Air Pump increases as the density of the air which it is handling decreases, gives it a singular suitability for such service.

The ideal air pump would be one in which the volumetric efficiency increased at such a rate that constant weight of air would be handled. While this is clearly impossible, careful tests show that the Westinghouse-Leblanc pump more nearly approaches the ideal than any other. Its volumetric efficiency increases rapidly, even after the reciprocating pump (due to limitations of clearance) has ceased to be of any value whatever.

The mechanical simplicity and ruggedness of the air pump makes it an ideal adjunct to the surface condenser. The only moving part of the pump is the rotor or impeller, marked J, which is a solid bronze casting practically indestructible under ordinary water conditions.

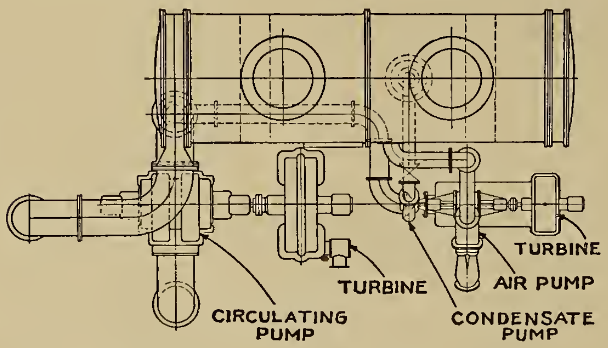
By referring to the figure on page 57 which shows an air and condensate pump mounted on the same shaft, it will be seen that air enters the pump through the pipe C. To start the pump in operation, high pressure steam is turned into the connection D. The cone forms the annular nozzle of a steam ejector, so that on opening the valve in the steam line a vacuum is created in the body of the air pump. The chamber E being piped up to a source of water supply, is immediately filled on account of the vacuum created by the steam ejector. Water then flows through the distributing nozzle F and is projected in layers through the combining passage G into the diffuser H. Between the successive layers of water, layers of air are imprisoned, these layers of water (on account of the high peripheral speed of the turbine wheel which throws them off) have a velocity sufficient to enable them to overcome the pressure of the atmosphere and force their way out of the pump in

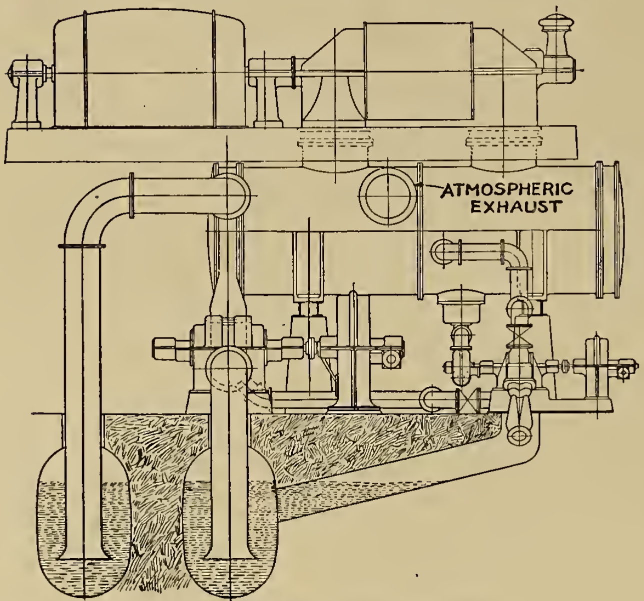


Cross-Section of Air and Condensate Pump

which a high vacuum exists. The layers of water act like a succession of water pistons with large volumes of air between them.

Cold water is used in the air pump; the specific heat of air is low and its weight small compared with that of the water, and therefore the air is immediately cooled on entering the pump to the lowest possible temperature.





—Typical Surface Condenser Installation

The water discharged from the air pump is not appreciably heated, and may therefore, be returned to the cold well. It must be remembered, however, that in reality a mixture of water and air is discharged, so that in discharging to the cold well, proper provision must be made for separating the air from the water.

The advantage of such a pump may easily be seen. There are no close clearances or rubbing surfaces requiring constant attention — no reciprocating parts with their attendant packing troubles.

It is obvious that the air handling capacity of this pump, owing to the use of water pistons, is much greater than the ordinary ejector arrangement where the air is simply carried along by friction. It is to be noticed that the water is discharged through a comparatively large opening through which small debris may pass without danger of clogging. Some hydraulic pumps of this general type, have a very narrow discharge opening extending around the entire circumference, and as a result much trouble is experienced from foreign matter, and it is often necessary to use perfectly clean water to insure satisfactory operation.

The pump that takes the condensed steam from the condenser is usually called the condensate pump. Although it is in point of size, probably the smallest of the condenser appurtenances, its function is just as important as that of the others. It draws the water from the high vacuum within the condenser and discharges it to the desired place,—usually the feed water tank.

This pump is of the single stage centrifugal type, usually driven by its own turbine. If desired, the condensate pump may be placed on the end of the air pump shaft.

The accompanying cut shows how readily the larger condensers may be placed directly beneath the turbine. In this particular case, the condensate and air pump are mounted on one shaft which is turbine driven. The circulating pump is also turbine driven.

The condensers described, have been developed for the production of high vacuua and are intended primarily for use with steam turbines where such vacuua may be effectively utilized.

They have been built in sizes ranging from one thousand to fifty thousand square feet in a single shell, the latter probably being the largest ever constructed.

CONDENSER TESTS

The following extracts from tests made on Westinghouse Surface Condensers after installation show in a striking manner how completely the air is removed from the steam space, and how closely the temperature of the condensate corresponds to that of the steam entering the condenser.

PUBLIC SERVICE ELECTRIC CO.
Marion, N. J.

Size — 20,000 Sq. Ft.
Connected to 9,000 K. W.
High Pressure Turbine.

Date, Oct. 26th, 1913.	3 P. M.	4 P. M.
Load in K. W. on Turbine	9,000	6,000
Barometer	30.16	30.14
Vacuum at top of Condenser by Mercury Column	28.96	29.05
Temperature at Top of Condenser °F.	83	79
Temperature Condensate Pump Water °F.	82	79
Vacuum at Air Pipe Connection	29.08	29.12
Temperature Injection Water Inlet °F.	66.5	68
Temperature Injection Water Discharge °F.	78	76

CAMBRIDGE ELECTRIC LIGHT CO.
Cambridge, Mass.

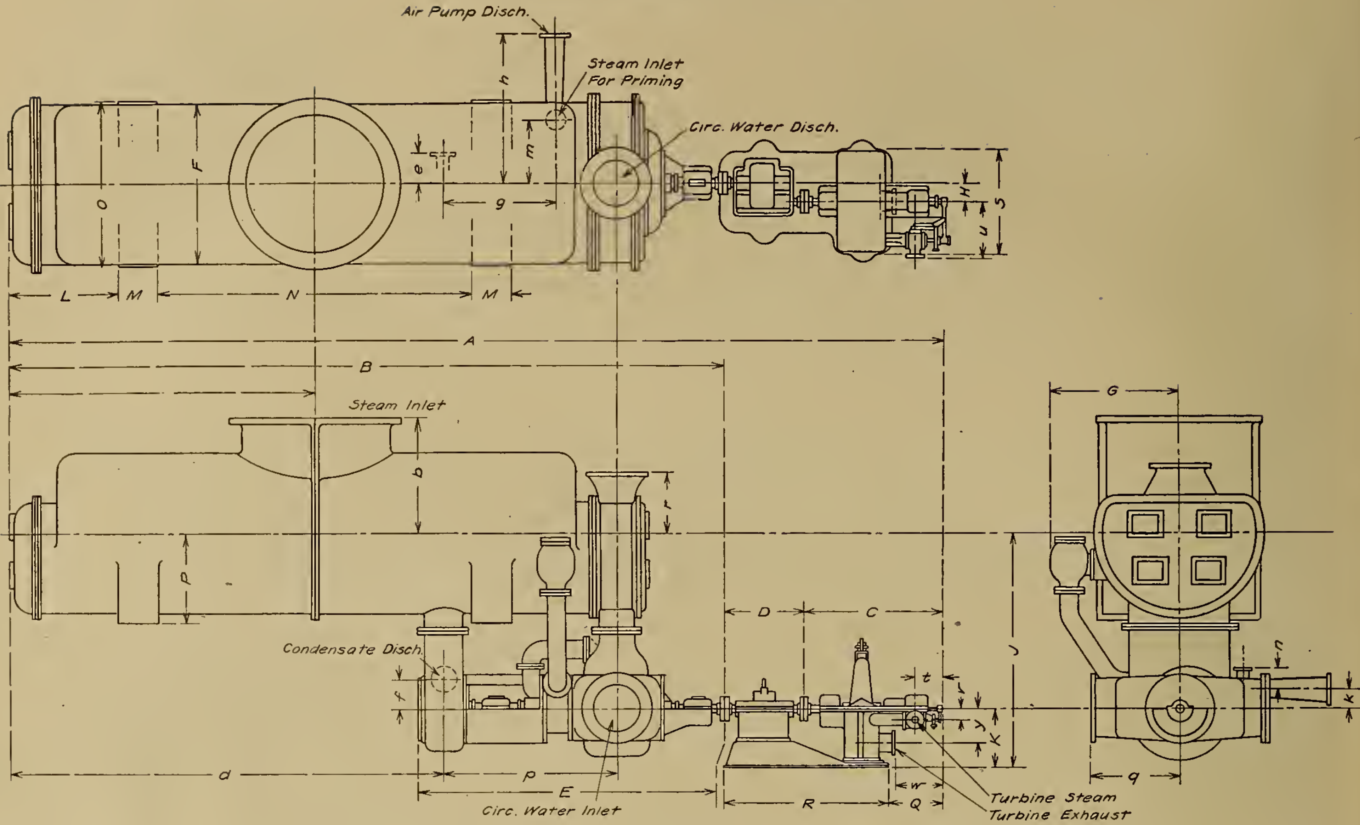
Size — 5,000 Sq. Ft.
Connected to 1,500 K. W.
Low Pressure Turbine.

Date, May 28th, 1913.	9 A. M.	11 A. M.	1 P. M.
Load in K. W. on Turbine	1,225	1,275	1,250
Barometer	29.88	29.88	29.88
Vacuum at Top of Condenser by Mercury Column	28.56	28.55	28.55
Temperature at Top of Condenser °F.	84	85.5	85
Temperature Condensate Pump Water °F.	82	82.5	82.5
Vacuum at Air Pipe Connection	28.7	28.66	28.65
Temperature Injection Water, Inlet °F.	59	59	59
Temperature Injection Water, Discharge °F.	77	77½	77

DETROIT UNITED RAILWAYS CO.
Monroe, Michigan.

Size — 4,000 Sq. Ft.
Connected to 2,000 K. W.
High Pressure Turbine.

Date, August 10th, 1913.	9 A. M.	9.30 A. M.	10 A.M
Load in K. W. on Turbine	2100	1800	2100
Barometer	29.25	29.25	29.25
Vacuum at Top of Condenser by Mercury Column	27.20	27.25	27.20
Temperature at Top of Condenser °F.	102	102	103
Temperature Condensate Pump Water °F.	100	100	101
Vacuum at Air Pipe Connection	27.20	27 25	27.25
Temperature Injection Water Inlet °F.	84	84	84
Temperature Injection Water Discharge	101	100	101



Area sq ft.	1000	2000	3000	4000	5000	Condensate dia.	3"	3"	4"	3"	3"
A	19'-0 1/8"	19'-10 9/16"	26'-3 5/8"	27'-0"	27'-5 5/8"	d	9'-6 3/8"	9'-4 1/2"	12'-10 1/2"	12'-6 1/2"	12'-4 7/8"
B	15'-9 5/8"	16'-8 1/16"	20'-9 9/16"	20'-7 3/16"	21'-0 13/16"	* e	9"	9"	7"	13"	13"
C	3'-2 1/2"	3'-2 1/2"	3'-2 1/2"	4'-1 1/4"	4'-1 1/4"	f	6 1/2"	6 1/2"	9"	10 1/2"	10 1/2"
D			2'-3 9/16"	2'-3 9/16"	2'-3 9/16"	Air Pump dia	3"	3 1/2"	6"	6"	6"
E	6'-10 1/4"	7'-10 9/16"	8'-7 9/16"	8'-9 7/16"	9'-4 11/16"	g	3'-0 5/8"	3'-0 5/8"	3'-2"	3'-2 7/8"	3'-2 7/8"
F	2'-7 1/2"	3'-7 3/4"	3'-11 3/4"	4'-6 3/4"	5'-1 1/4"	* h	2'-4"	2-8 1/2"	4'-3 1/2"	3'-11 3/4"	4'-1 3/4"
* G	2'-4 1/8"	2'-8 3/8"		3'-7 5/8"	3'-11 1/2"	k	3 3/8"	3 3/8"	6"	5"	5"
H			6 3/16"	6 3/16"	6 3/16"	Priming dia.	1 1/2"	2"	2"	2"	2"
J	4'-9 1/8"	5'-5 1/8"	6'-5 1/8"	6'-8 1/4"	7'-3 1/4"	* m	13 5/8"	14 7/8"	22"	20 1/4"	20 1/4"
K	17 1/8"	17 1/8"	18 1/8"	20 1/4"	20 1/4"	ϕ n	3 1/8"	3 1/8"	12 3/4"	11 3/4"	11 3/4"
L	23 5/8"	2'-9 1/8"	2'-7 5/8"	3'-3 3/8"	2'-9 3/8"	Circ. Inlet dia	7"	12"	14"	16"	18"
M	6"	10"	10"	14"	14"	p	4'-1 1/2"	4'-7 1/8"	4'-11"	4'-11 5/8"	5'-3 1/4"
N	8'-3"	7'-0"	11'-2"	8'-10"	10'-0"	q	16"	18"	2'-2"	2'-6"	2'-4"
O	2'-6"	3'-4"	3'-9"	4'-8"	4'-10"	Circ. Disch. dia.	7"	12"	14"	16"	18"
P	18"	23"	2'-4"	2'-7"	2'-10"	r	12"	15"	18"	19"	21"
Q	12 1/2"	12 1/2"	11 1/2"	19 1/16"	19 1/16"	Turb. St. dia	2 1/2"	2 1/2"	2 1/2"	2 1/2"	2 1/2"
R	18"	18"	4'-8 1/8"	4'-11 7/16"	4'-11 7/16"	t	12 1/2"	12 1/2"	12 1/2"	10 7/8"	10 7/8"
S	2'-7"	2'-7"	2'-7 3/4"	2'-11 3/4"	2'-11 3/4"	u	15 1/2"	15 1/2"	15 1/2"	19"	19"
St. Inlet dia.	22"	36"	42"	48"	48"	v	4 1/2"	4 1/2"	4 1/2"	3 11/16"	3 11/16"
a	6'-11 5/8"	7'-1 1/8"	9'-0 5/8"	8'-10 3/8"	8'-11 3/8"	Turb. Ex. dia.	4"	4"	4"	6"	6"
b	23 1/4"	1'-7 1/2"	2'-8"	3'-0"	3'-3"	w	17 1/4"	17 1/4"	17 1/4"	17 11/16"	17 11/16"
						y	11"	11"	11"	11 1/2"	11 1/2"

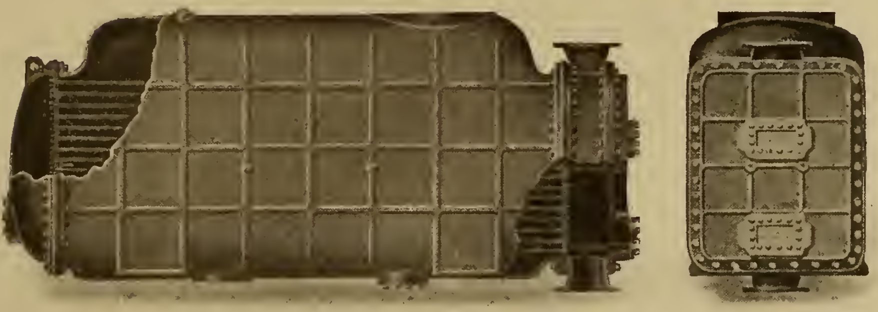
Note:—

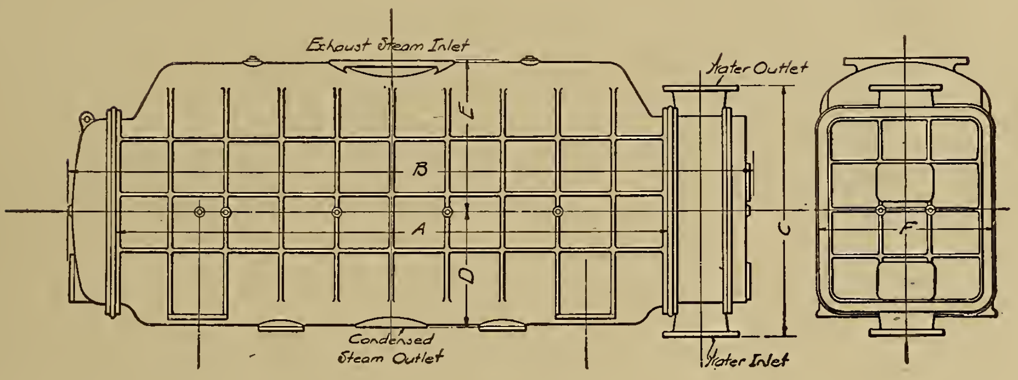
In the 1000 and 2000 sq. ft. sizes no reducing gear is used, the turbine couples direct to pumps.

* Where no reducing gear is used these connections are on other side of condenser from that shown in diagram.

ϕ In two smallest sizes priming connection opens downward.

THE WHEELER CONDENSER AND ENGINEERING COMPANY
WHEELER ADMIRALTY SURFACE CONDENSER

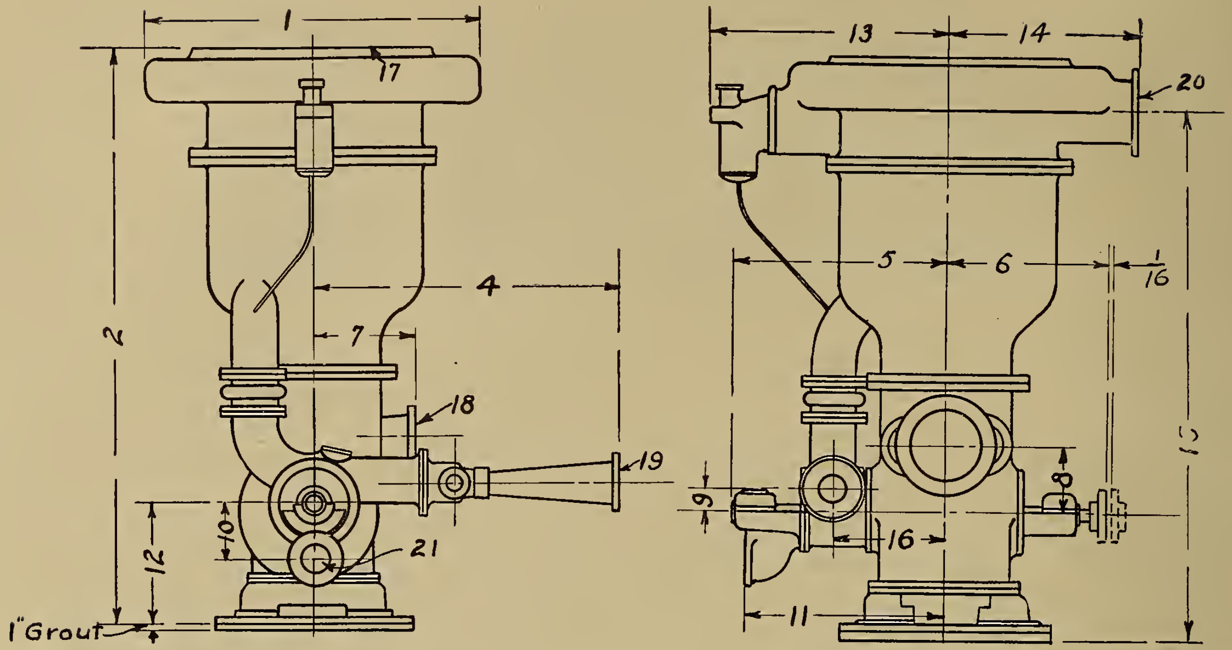




Sq. Ft. of Surface	A	B	C	D	E	F	Diameter of Tube	Weight Lbs.
463	7′-0″	8′-3″	3′-0″	15¾″	21¾″	18¼″	⅝″	3400
606	8′-0″	9′-4″	3′-1″	16¼″	22¼″	22⅛″	⅝″	4500
751	8′-0″	9′-7″	3′-0″	16⅛″	22¼″	2′-1″	⅝″	5200
1042	8′-0″	9′-8″	3′-5″	18¾″	2′-2½″	2′-3⅛″	⅝″	6600
1109	8′-0″	9′-5″	3′-8″	19⅝″	2′-2⅞″	2′-4¼″	¾″	7200
1379	8′-0″	10′-0′	4′-0″	22⅛″	2′-5⅝″	2′-9⅜″	¾″	9200
1778	8′-0″	10′-2″	4′-4″	23¼″	2′-8¼″	3 -2″	¾″	11100
2051	8′-0″	10′-2″	4′-8″	2′-1″	2′-11½″	3′-4″	¾″	12900
2223	10′-0″	12′-5″	4′-6″	2′-1″	2′-8½″	3′-2″	¾″	14000
2757	8′-0″	10′-8″	5′-4″	2′-3¼″	2′-9⅜″	3′-10″	¾″	16200
3446	10′-0″	12′-7″	5′-4″	2′-5½″	3′-1½″	3′-10″	¾″	19600
4135	12′-0″	14′-7″	5′-4″	2′-5½″	3′-1½″	3′-10″	¾″	23000
4679	12′-0″	15′-0″	5′-6″	2 -6″	3′-4½″	4′-½″	¾″	26500
5069	13′-0″	16′-0″	5′-6″	2′-6″	3′-4½″	4′-½″	¾″	28300
5849	15′-0″	18′-0″	5′-6″	2′-6″	3′-4½″	4′-½″	¾″	31800
6733	15′-0″	17′-0″	5′-8″	2′-7″	3′-7½″	4′-6″	¾″	36900
7714	13′-0″	16′-0″	6′-6″	3′-0″	4′-2½″	5′-2½″	¾″	44200
8307	14′-0″	17′-0″	6′-6″	3′-0″	4′-2½″	5′-2½″	¾″	46700

WESTINGHOUSE LE BLANC JET CONDENSERS

SIZES



Sze	1	2	4	5	6	7	8	9	10	11	12	13	14	15	16	Dia. Openings				
																17	18	19	20	21
1	3″-4½	6″-6¾	30	33⅜	26½	16¾	15⅛	10	9½	25½	22⅜	35⅝	2	6″-1¼	13⅝	22	5	3	6	5
2	3″-4½	6″-6¾	31½	33⅜	26½	16¾	15⅛	10	9½	25⅛	22⅜	35⅝	2	6″-1¼	13⅝	22	5	3	6	5
4	3″-10½	7″-1⅞	33	34	27¾	18	15½	10	9½	25¾	23⅛	3″-2⅞	28½	6″-6⅞	14¼	28	6	3½	7	5
5	3″-10½	7″-1⅞	35⅛	34	27¾	18	15½	10	9½	25¾	23⅛	3″-2⅞	28½	6″-6⅞	14¼	28	6	4	7	5
7	4″-4½	8″-5½	3″-3	35 15/16	27⅛	20	17¾	10	10½	30¼	25	3″-5⅞	31⅜	7″-10	15¼	30	7	4	9	6
8	4″-4½	8″-5½	3″-7	35 15/16	27⅛	20	17¾	10	10½	30¼	25	3″-5⅞	31⅜	7″-10	15¼	30	7	5	9	6
10	5″-0	8″-8¼	3″-10½	35 15/16	27⅛	20	18⅛	10	10½	30¼	25¼	3″-9⅝	35	7″-10¾	15¼	36	9	6	12	6
11	5″-0	8″-8¼	4″-0½	35 15/16	27⅛	20	18⅛	10	10½	30¼	25¼	3″-9⅝	35	7″-10¾	15¼	36	9	6	12	6
13	5″-7½	9″-10⅞	4″-8	3″-7⅞	34⅞	21	19	10	11¾	35¾	28⅝	4″-1⅜	3″-3	8″-11⅞	20¼	42	12	6	14	6
14	5″-7½	9″-10⅞	5″-0	3″-7⅞	34⅞	21	19	10	11¾	35¾	28⅝	4″-1⅜	3″-3	8″-11⅞	20¼	42	12	7	14	6
16	6″-7½	10″-11⅜	5″-6¾	3″-10 11/16	3″-1 1/16	24	19¾	9⅞	14	3″-7	29⅝	4″-8½	3″-7½	9″-11⅜	22½	48	14	8	16	10
17	6″-7½	10″-11⅜	6″-0	3″-10 11/16	3″-1 1/16	24	19¾	9⅞	14	3″-7	29⅝	4″-8½	3″-7½	9″-11⅜	22½	48	14	9	16	10
18	7″-5½	13″-5½	6″-4½	4″-6 15/16	3″-8 3/16	3″-10¼	18⅞	9⅞	14	4″-3¼	29½	5″-1½	4″-2	12″-2½	29¾	54	18	9	20	10
19	7″-5½	13″-5½	6″-8½	4″-6 15/16	3″-8 3/16	3″-10¼	18⅞	9⅞	14	4″-3¼	29½	5″-1½	4″-2	12″-2½	29¾	54	18	9	20	10

WESTINGHOUSE LEBLANC JET CONDENSERS CAPACITIES

Turbine Driven

Based on 5° Terminal Difference.

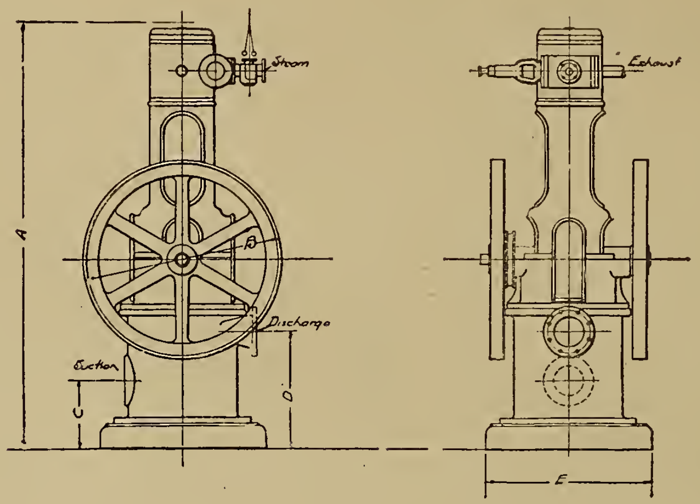
Con-denser	Circulating Water	28″ VACUUM									
Number	Lbs.per Hr.	35° F.	40° F.	45° F.	50° F.	50° F.	55° F.	60° F.	70° F.	75° F.	80° F.
1	235,000	17200	15750	14400	13000	11575	10150	8750	7300	5950	4500
2	320,000	20800	19200	17400	15700	14000	12250	10500	8800	7200	5450
4	350,000	22750	20750	19000	17100	15880	13400	11600	9550	7800	5950
5	400,000	26000	23800	21700	19600	17500	15325	13200	11050	9025	6820
7	600,000	39000	35750	32750	29000	26400	23000	19750	16600	13400	10250
8	750,000	49000	44750	40750	37000	32750	29000	24800	20500	16750	12850
10	825,000	53500	49000	44750	40400	34750	31800	27300	22750	18400	14100
11	940,000	61000	55800	51000	46000	41000	36000	31000	25750	21000	16000
13	1,200,000	77500	71000	65200	58600	52750	46000	39250	33250	26600	20500
14	1,550,000	100600	92500	84000	75750	57750	59300	51150	42750	34650	26400
16	1,850,000	120500	11000	100500	91000	81000	71000	61000	51000	41500	31600
17	2,200,000	143000	131000	119000	107500	96000	84000	72500	60800	49250	37500
18	2,620,000	170000	156000	142000	128000	114500	100320	86300	72250	58600	44500
19	3,000,000	194700	178500	163000	147000	131000	115000	99040	82000	67000	51100
20	4,000,000	260000	238000	217500	196000	174600	153200	132000	110300	89400	68100
21	5,000,000	325000	298000	271500	245000	218500	191500	165300	138000	111600	85200
22	6,000,000	289000	357000	325000	293000	262000	230000	198000	166000	134000	102000
23	7,000,000	455000	416000	380000	342000	305000	268000	231000	194000	156000	119000
24	9,000,000	580000	530000	485000	447000	390000	344000	295000	248000	212000	153000
25	11,000,000	710000	650000	590000	545000	475000	420000	360000	304000	258000	187000
26	13,000,000	840000	770000	700000	645000	560000	495000	425000	360000	305000	220000

The figures given are based on the assumption that the temperature of the mixture of water and steam is 5 degrees less than the theoretical temperature corresponding to the vacuum.

The following conditions are assumed:

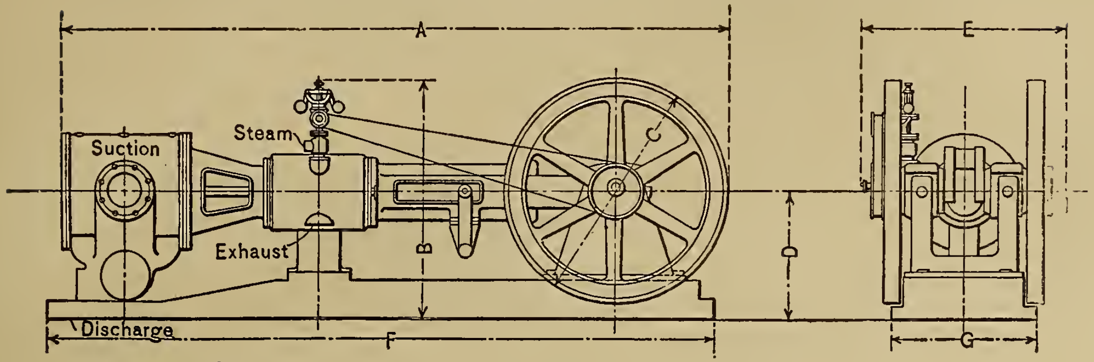
1. That condenser pumps are steam driven.
2. Temperature of injection water . . . . 70 Degress F.
3. Level of water supply below top of condenser does not exceed . . . . 13 Feet
4. Discharge water is to be elevated above base of condenser, not to exceed (including pipe friction) . . . . 4 Feet
5. Suction pipe is to be so arranged that friction head will not exceed the equivalent of. 2 Feet
6. Vacuum at rated load, referred to a barometric pressure at 30 inches . . . 28 Inches

THE WHEELER CONDENSER AND ENGINEERING COMPANY
DIMENSIONS OF WHEELER-EDWARDS AIR PUMP



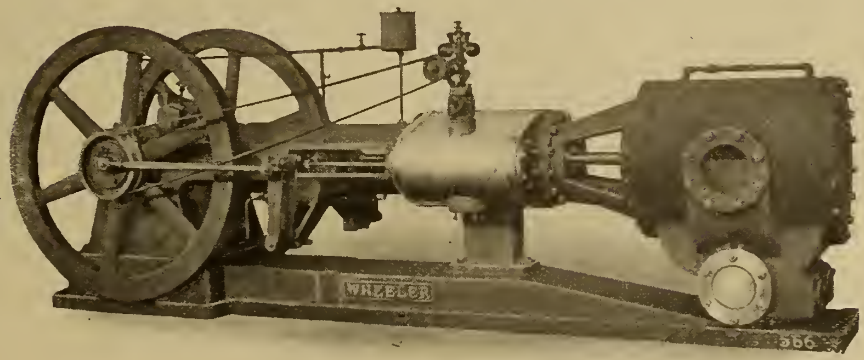
Size	Capacity in lbs. per hour 28" Vac.	Suction	Discharge	A	B	C	D	E
3½x8x6	2250	3"	3"	5'-2½"	2'-3"	8⅞"	16⅜"	22"
4x10x8	4500	4"	4"	6'-7"	2'-6"	10½"	20½"	2'-6"
5x12x10	7500	5"	5"	7'-9"	3'-0"	13"	24¾"	3'-0"
6-14-10	10750	6"	6"	8'-2"	3'-6"	15"	2'-2½"	3'-3"
7-16-10	14000	6"	6"	8'-8"	4'-0"	15¼"	2'-2"	3'-6"
8-18-12	20750	7"	7"	9'-6"	4'-6"	18"	2'-8"	3'-9"
8-20-12	26000	8"	8"	9'-8"	4'-6"	18¾"	2'-8"	3'-9"
9-24-12	36750	10"	10"	9'-10"	5'-0"	21½"	2'-10½"	4'-4"
10-26-12	43250	12"	10"	10'-8"	5'-0"	23⅛"	3'-0"	4'-4"
12-30-14	62500							

THE WHEELER CONDENSER AND ENGINEERING COMPANY
DIMENSIONS OF WHEELER ROTATIVE DRY VACUUM PUMP



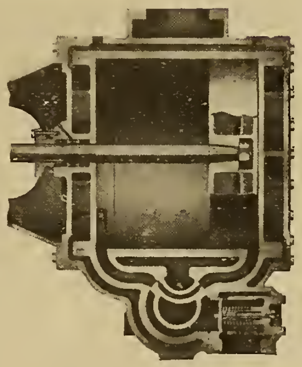
Size	Capacities for Condenser Surface in lbs. per hr. 28 ' Vac.	Size Suction	Size Discharge	A	B	C	qD	E
5-12-12	18000	4″	2″	9′-11½″	3′-1″	3′-3″	17½″	2′-1″
7-14-14	27400	4½″	3″	11′ 3⅜″	3′-6″	3′-6″	20″	3′-4″
7-16-10	34600	5″	3″	11 -3⅜″	3′-8″	3′-6″	22″	3′-4″
9-18-16	48000	6″	4″	13 -4″	4′-3″	4′-6″	24″	4′-1″
9-22-16	68600	8″	4½″	13′-5½″	4′-7″	4′-6″	2′-4½″	4′-1″
10-26-18	102600	9″	5″	15′-5½″	5′-¾″	5′-6″	2′-8½″	5′-0″
12-30-18	130000	10″	6″	15′-7″	6′-3¼″	5′-6″	3′-4″	5′-0″
14-34-18	154600	14 ′	6″	15′-6″	6′-4″	5′-6″	3′-5″	5′-3½″
16-30-24	160000	10″	6″	19′-9″	6′-7½″	7′-0″	3′-½″	5′-9″
16-36-24	197000	16″	8″	20′-7¾″	6′-5″	7′-0″	2′-9½″	5′-9″

Note:—For 26″ Vacuum capacity may be doubled.
For 27″ Vacuum capacity is 50% greater.
For 28½″ Vacuum capacity is 25% less.



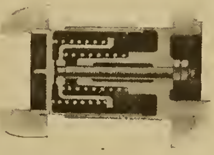
LONGITUDINAL SECTION OF AIR CYLINDER

showing Rotative Valve and Flash Port for minimizing clearance loss.

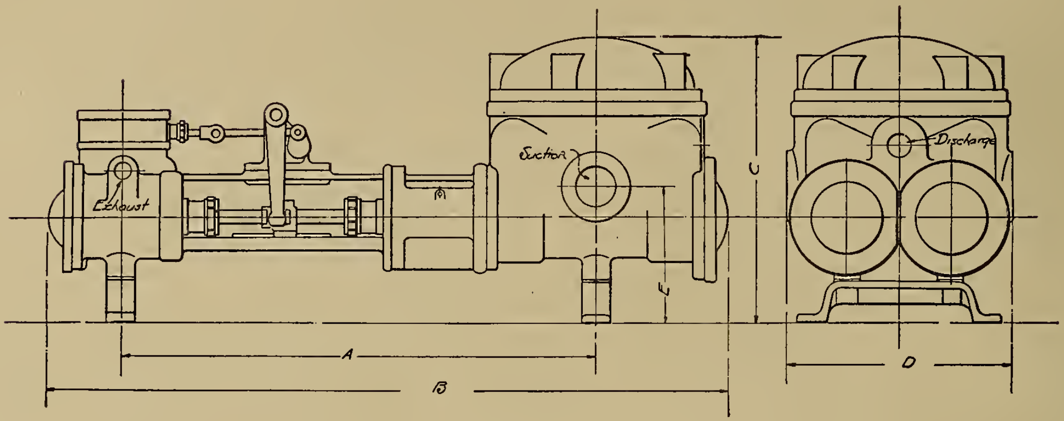


WHEELER PATENT COMPOUND DISCHARGE VALVE

The lift if regulated by outside adjusting screws; if water collects in the cylinder the secondary spring compresses and gives extra large lift.

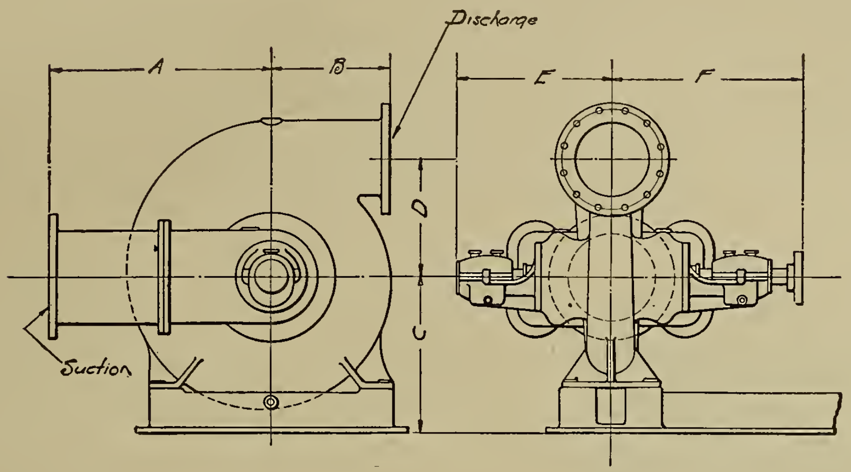


THE WHEELER CONDENSER AND ENGINEERING COMPANY
WHEELER DUPLEX HOT WELL PUMP



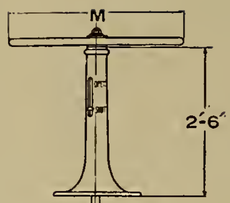
Size	Capacity lbs. per hour	Suction	Discharge	A	B	C	D	E
3x2¾x3	4200	2″	1½″	21⅞″	2′-7¼″	12⅛″	10¾″	5¼″
4½x4x4	11500	2½″	1½″	3′-6⅜″	3′-6⅜″	17⅝″	14″	8⅜″
5¼x4¾x5	19000	3″	2½″	3′-10¼″	3′-10¼″	18⅝″	16″	9 5/16″
6x5¾x6	33500	4″	3″	4′-0′	4′-0″	2′-1″	22″	14¾″
6x7½x6	57000	6″	5″	4′-10″	4′-10″	2′-6¼″	2′-1½″	15″
6x8½x6	73500	6″	5″	4′-10″	4′-10″	2′-6¼″	2′-1½″	15″
7½x8½x10	98000							
10x10x10	142000	8″	7″	6′-¾″	6′-¾″	3′-4¼″	3′-6½″	7½″
10x12x10	195600	10″	8″	6′-1½″	6′-1½″	2′-9½″	3′-11″	8¼″

THE WHEELER CONDENSER AND ENGINEERING COMPANY
WHEELER CENTRIFUGAL PUMP



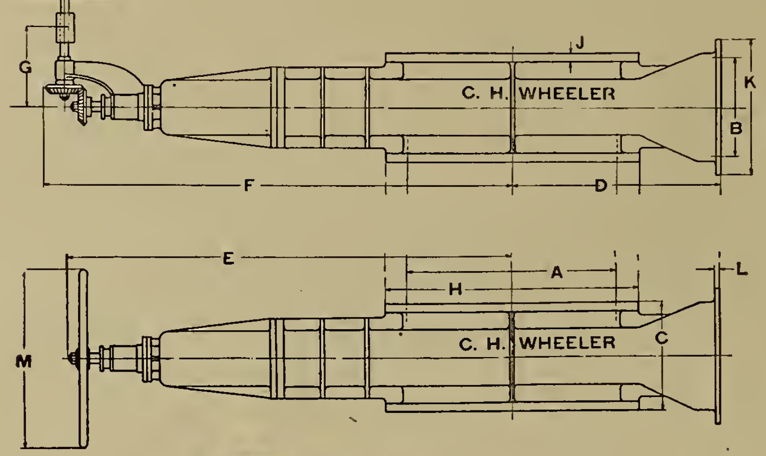
Size	Gallons per Minute	A	B	C	D	E	F
4″	400–475	18⅝″	12½″	15¾″	9¾″	17⅝″	21¾″
5″	600–725	22″	12½″	20¾″	11½″	19⅜″	23 1/16″
6″	900–1050	23″	15″	22½″	12″	21½″	2′-1″
8″	1600–1900	2′-3½″	16″	21⅛″	14½″	2′-2″	2′-5⅜″
10″	2500–3000	2′-7″	18″	24¾″	16″	2′-6¼″	2′-11¼″
12″	3500–4200	3′-½″	22″	2′-4½″	18½″	2′-9″	3′-4″
14″	4800–5600	3′-6″	22″	2′-6⅞″	21¾″	2′-6¼″	2′-11¾″
16″	6400–7500	3′-9″	23½″	2′-8¼″	23½″	2′-9¼″	3′-2½″
18″	8000–9500	4′-1½″	2′-1″	3′-2″	2′-0″	3′-2¾″	3′-11½″
20″	10000–11600	4′-1″	2′-3″	2′-11″	22½″	3′-4½″	4′-½″
24″	14000–17000	4′-10½″	2′-8″	4′-0″	2′-4″	4′-0″	4′-8″
30″	22000–26000	5′-4″	3′-3″	3′-10″	3′-2″	5′-½″	5′-7″

C. H. WHEELER SPECIAL EXHAUST GATE VALVE



DIMENSIONS

Size of Valve A	B	C	D	E	F	G	H	J	K	L	M
16	8	14	16	42	48	10	23½	1⅜	13½	1⅛	16
20	10	14	20	54	53	11⅝	27½	1½	16	1⅛	20
24	10	16¾	24	55	59	13	32	1½	16	1⅛	20
30	14	18	30	65	69	14⅛	38¾	1¾	21	1⅜	24
36	18	20	33	77	83	16	46¼	1¾	25	1½	36
42	20	22	42	89	95	16	53¼	2	27½	1½	36

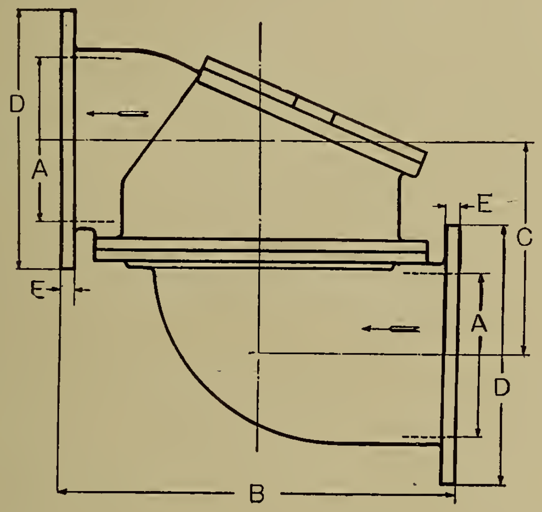


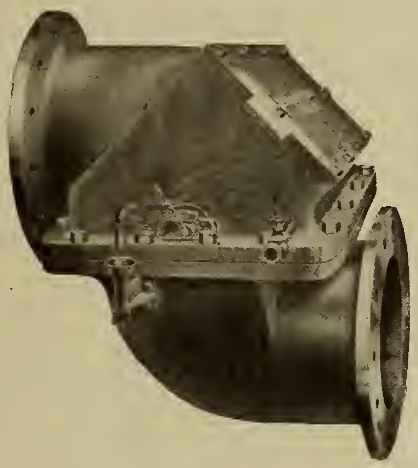
Surface Condenser with Multiflex Automatic Relief Valve, Gate Valve and Expansion Joint.

THE C. H. WHEELER "MULTIFLEX" PATENT EXHAUST RELIEF VALVE

This valve consists of a brass valve deck which is indived into a number of rectangular ports arranged in rows, each port accurately faced on an angle and covered by a flap valve made of Phosphor Bronze sheet, coiled at one end. The valves in each row are mounted on, and controlled by, a slotted bronze stem, to one end of which is keyed a bronze crank; these cranks have a common connecting rod which communicates with an external lever and locking device which not only allows the valves to be secured in either an open or closed position, but the valves can be seated with any desired degree of tension, because of the coiled spring. The angle of the ports and valve seats avoids abrupt turns and gives the steam an easy, smooth and noiseless passage through the valve.

In normal operation the vacuum, or unbalanced condition of the atmosphere, holds the valves tightly on their seats; but to insure absolute tightness for high vacuum service, a water seal with brass globe valve on inlet side and visible funnel overflow with drain connection on discharge is provided.

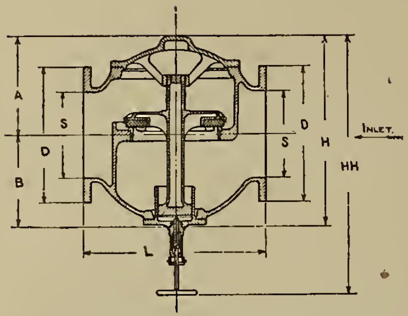




DIMENSIONS

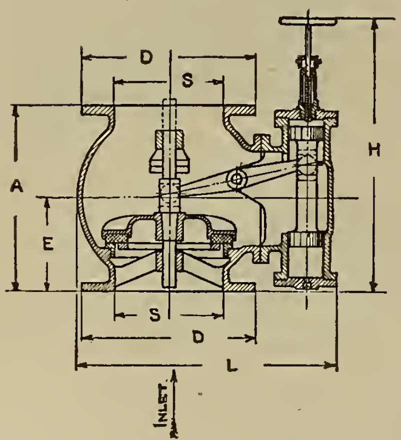
Size of Valve A	B	C	D	E	Shipping Weight
6	28¾	9½	11	1⅛	330 lbs.
8	28¾	9½	13½	1⅛	384 "
10	29	13½	16	1⅛	900 "
12	29	15½	19	1¼	975 "
14	37	12	21	1⅜	1128 "
16	42	13	23½	1⅜	1440 "
18	37	21	25	1½	1995 "
20	45	19½	27½	1½	2440 "
24	56	26¼	32	1½	3822 "
30	64	26	38¾	1¾	6000 "

KNOWLES VERTICAL AUTOMATIC EXHAUST RELIEF VALVE



With screw lifting device

S	D	L		H	A	B	HH			
Size	Diameter of Flanges	Length	Width	Height	Height above Centre	Distance below Centre	Height Over All	Thickness of Flanges	Diameter of Bolt Circle	Number and Size of Bolts
4	9	12	9	$10\frac{13}{16}$	$5\frac{11}{16}$	$5\frac{1}{8}$	$16\frac{9}{16}$	$\frac{3}{4}$	$7\frac{1}{2}$	4—$\frac{5}{8}$
5	10	$13\frac{1}{2}$	$11\frac{1}{4}$	13	$6\frac{1}{2}$	$6\frac{1}{2}$	$19\frac{7}{8}$	$\frac{7}{8}$	$8\frac{1}{2}$	8—$\frac{5}{8}$
6	11	15	$12\frac{7}{8}$	$14\frac{13}{16}$	$7\frac{3}{8}$	$7\frac{7}{16}$	$21\frac{11}{16}$	$\frac{7}{8}$	$9\frac{1}{2}$	8—$\frac{5}{8}$
8	$13\frac{1}{2}$	18	17	$17\frac{3}{4}$	$9\frac{1}{4}$	$8\frac{1}{2}$	25	1	$11\frac{3}{4}$	8—$\frac{5}{8}$
10	16	24	23	$23\frac{5}{8}$	$11\frac{3}{4}$	$11\frac{7}{8}$	$31\frac{3}{4}$	$1\frac{1}{8}$	$14\frac{1}{4}$	12—$\frac{3}{4}$
12	19	26	25	$27\frac{3}{8}$	$14\frac{1}{2}$	$12\frac{7}{8}$	$37\frac{3}{8}$	$1\frac{1}{8}$	17	12—$\frac{3}{4}$
14	21	32	29	$31\frac{3}{8}$	$16\frac{3}{8}$	15	43	$1\frac{1}{4}$	$18\frac{3}{4}$	12—$\frac{7}{8}$
16	$23\frac{1}{2}$	36	32	$34\frac{3}{4}$	18	$16\frac{3}{4}$	$49\frac{3}{8}$	$1\frac{1}{2}$	$21\frac{1}{4}$	16—$\frac{7}{8}$
18	25	42	$36\frac{3}{4}$	$38\frac{3}{8}$	$19\frac{5}{8}$	$18\frac{3}{4}$	$54\frac{1}{8}$	$1\frac{1}{2}$	$22\frac{3}{4}$	16—1
20	$27\frac{1}{2}$	48	$41\frac{3}{4}$	$42\frac{3}{8}$	$21\frac{1}{8}$	$21\frac{1}{4}$	$58\frac{1}{8}$	$1\frac{3}{4}$	25	20—1
22	$29\frac{1}{2}$	48	$42\frac{1}{4}$	$43\frac{3}{8}$	$21\frac{3}{8}$	22	$61\frac{1}{4}$	$1\frac{3}{4}$	$27\frac{1}{4}$	20—1
24	$31\frac{1}{2}$	52	$43\frac{1}{4}$	$46\frac{1}{2}$	$24\frac{1}{4}$	$22\frac{1}{4}$	$64\frac{3}{8}$	$1\frac{3}{4}$	$29\frac{1}{4}$	20—1
26	$33\frac{3}{4}$	58	50	52	26	26	$72\frac{1}{2}$	2	$31\frac{1}{4}$	24—1
28	36	66	56	$59\frac{3}{8}$	$29\frac{3}{8}$	$29\frac{3}{4}$	$83\frac{7}{8}$	2	$33\frac{1}{2}$	28—1
30	38	72	$60\frac{1}{2}$	$63\frac{1}{2}$	$31\frac{1}{2}$	32	$87\frac{3}{4}$	2	$35\frac{1}{2}$	28—$1\frac{1}{8}$



Double dash pot with screw lifting device

S	D	A	L		H	E			
Size	Diam. of Flanges	Height Face to Face	Length	Width	Height	Distance from Centre to Inlet	Thick-ness of Flanges	Diam. of Bolt Circle	Number and Size of Bolts
4	9	$9\frac{1}{2}$	$14\frac{1}{2}$	9	$14\frac{1}{2}$	$4\frac{3}{4}$	$\frac{3}{4}$	$7\frac{1}{2}$	4-$\frac{5}{8}$
5	10	11	$14\frac{5}{8}$	$10\frac{1}{4}$	$16\frac{5}{8}$	$5\frac{1}{2}$	$\frac{7}{8}$	$8\frac{1}{2}$	8-$\frac{5}{8}$
6	11	13	$16\frac{3}{4}$	$11\frac{1}{4}$	19	$6\frac{1}{2}$	$\frac{7}{8}$	$9\frac{1}{2}$	8-$\frac{5}{8}$
8	$13\frac{1}{2}$	18	$21\frac{3}{4}$	16	25	9	1	$11\frac{3}{4}$	8-$\frac{5}{8}$
10	16	19	$24\frac{3}{8}$	18	$28\frac{5}{8}$	$9\frac{1}{2}$	$1\frac{1}{8}$	$14\frac{1}{4}$	12-$\frac{3}{4}$
12	19	20	$28\frac{1}{2}$	20	$29\frac{5}{8}$	10	$1\frac{1}{8}$	17	12-$\frac{3}{4}$
14	21	23	$32\frac{5}{8}$	$23\frac{1}{2}$	34	$11\frac{1}{2}$	$1\frac{1}{4}$	$18\frac{3}{4}$	12-$\frac{7}{8}$
16	$23\frac{1}{2}$	27	$36\frac{3}{4}$	$27\frac{1}{2}$	42	$13\frac{1}{2}$	$1\frac{1}{2}$	$21\frac{1}{4}$	16-$\frac{7}{8}$
18	25	30	$40\frac{1}{4}$	31	$44\frac{5}{8}$	15	$1\frac{1}{2}$	$22\frac{3}{4}$	16-1
20	$27\frac{1}{2}$	34	$44\frac{1}{2}$	$34\frac{3}{4}$	51	17	$1\frac{3}{4}$	25	20-1
22	$29\frac{1}{2}$	36	$49\frac{1}{4}$	$36\frac{1}{4}$	56	18	$1\frac{3}{4}$	$27\frac{1}{4}$	20-1
24	$31\frac{1}{2}$	37	$49\frac{5}{8}$	$38\frac{1}{4}$	58	$18\frac{1}{2}$	$1\frac{3}{4}$	$29\frac{1}{4}$	20-1
26	$33\frac{3}{4}$	42	55	42	63	21	2	$31\frac{1}{4}$	24-1
28	36	46	59	46	67	23	2	$33\frac{1}{2}$	28-1
30	38	50	63	50	72	25	2	$35\frac{1}{2}$	28-$1\frac{1}{8}$

FLOW OF STEAM IN PIPES

The area of a steam pipe, if the pipe is of short length, may be calculated by dividing the volume of steam to be delivered per minute by an assumed velocity of flow. For engines of the Corliss type taking steam in large quantities intermittently, a velocity not exceeding 6000 feet per minute may be used. A receiver having a volume equal to three times the capacity of the high pressure cylinder is sometimes placed close to the throttle valves of such engines. This receiver furnishes a reservoir from which the engine draws steam; it enables a smaller steam pipe to be used and thereby *prevents* the vibrations of the steam main which are so common in plants where slow speed engines are in use. For steam turbines or high speed engines which practically make a steady flow a velocity as high as 10,000 feet per minute may be used. The drop in pressure in a pipe of long length may be calculated by the formulae proposed by Mr. G. H. Babcock. These formulae are based on actual tests made on pipes up to 4″ in diameter, and it is probable that the results will hold good for pipes of even larger size. Similar tests were conducted by R. C. Carpenter and a formula derived which is practically the same as that proposed by Babcock. In the formula:

w = weight of steam in lbs. per minute.
d = diameter of pipe in inches.
L = length of pipe in feet.
P = drop in pressure in lbs. per sq. inch.
y = *mean* density in lbs. per cu. ft.
V = velocity in feet per minute.

$$V = 19{,}590 \sqrt{\frac{Pd}{yL\left(1+\frac{3.6}{d}\right)}}$$

$$w = 87 \sqrt{\frac{Py\,d^5}{L\left(1+\frac{3.6}{d}\right)}}$$

$$P = .0001321 \frac{w^2 L\left(1+\frac{3.6}{d}\right)}{y\,d^5}$$

VELOCITY OF EXHAUST STEAM

The velocity of exhaust steam is taken from 6000 feet per minute for steam at 3 pounds back pressure to 40,000 feet per minute at a 29.5″ vacuum. As the pressure gets lower the velocity increases, and some engineers use velocities which would increase from 20,000 feet per minute at a 26″ vacuum to 35,000 feet per minute for a 29″ vacuum. There has been in the past but little information as to the drop in pressure or the loss of vacuum due to these high velocities. Two series of experiments were carried on in the engineering laboratories at M. I. T. to determine the loss of pressure with such velocities. These experiments were with a pipe 6″ in diameter.

While the results apply specifically to a pipe of about this size it is probable that the equations may be used for pipes of larger sizes. No doubt the drop in pressure in the larger size pipe will be less than given by the equation. These experiments cover a range from a 25″ vacuum through

29½″. The formulae proposed are modifications of the Babcock formula and the letters used have the same meaning, i. e.:

L = the length of pipe in feet.
y = the mean density of the steam in lbs. per cu. ft.
V = mean velocity of the steam in ft. per min.
P = *difference* in pressure in lbs. per sq. inch.
d = diameter of the pipe in inches.

$$V = 13{,}700 \sqrt{\frac{Pd}{y\,L\left(1 + \frac{3.6}{d}\right)}} \text{ for straight pipe.}$$

$$P = .0001791 \frac{w^2\,L\left(1 + \frac{3.6}{d}\right)}{y\,d^5} \text{ for straight pipe.}$$

$$V = 9600 \sqrt{\frac{Pd}{y\,L\left(1 + \frac{3.6}{d}\right)}} \text{ for a 90° elbow.}$$

$$V = 7200 \sqrt{\frac{Pd}{y\,L\left(1 + \frac{3.6}{d}\right)}} \text{ for two 90° elbows making a return bend.}$$

The accuracy of the work does not warrant calculation of results within velocities of 500 feet either side of the true velocity.

Problem to Illustrate Application of Formula. Suppose that the exhaust pipe leading from a turbine to a condenser is 15′ long, 20″ diameter, with an elbow at each end. If it be assumed that the steam has a mean velocity of 30,000 feet per minute, what will be the drop in pressure between the turbine and the condenser? The vacuum midway between the turbine and the condenser being 28½″, barometer 29.95″.

The absolute pressure is .933 lbs. and the specific volume of steam at this pressure is 355 cu. ft.

$$\text{For the straight pipe } 30{,}000 = 13{,}700 \sqrt{\frac{P \times 20}{\frac{1}{355} \times 15\left(1 + \frac{3.6}{20}\right)}}$$

$$P = .012 \text{ lbs.}$$

$$\text{For each elbow } 30{,}000 = 9600 \sqrt{\frac{P \times 20}{\frac{1}{355} \times 2\left(1 + \frac{3.6}{20}\right)}}$$

$$P = .003$$

Note:— The length of the elbow is taken as 2 ft. along the center line.
The total loss is .012 + .003 + .003 = .018 lbs.

$$\frac{.018}{.491} = .04'' \text{ of mercury pressure.}$$

The loss resulting from an elbow is equivalent to the loss in a piece of straight pipe having a length a little greater than twice the distance along the center line of the elbow.

Example to Illustrate

An engine is connected to a barometric tube condenser through 40 feet of vertical pipe, 10 feet of horizontal pipe and three elbows; one elbow being located at the exhaust opening of the cylinder and the second and third elbows being on the vertical pipe leading to the condenser.

The exhaust pipe is 12″ diameter and the vacuum to be maintained is 26″, with the barometer at 30.1″. If the maximum difference in pressure between the condenser and the engine is to be not over .1″ of Hg. how many pounds of steam per hour can be put through this 12″ pipe?

The length through the center of a 12″ elbow is about 1 foot so that about 1 × 2 × 3 = 6 feet should be added to the length of the pipe making a total of 56 feet.

$$V = 13{,}700\sqrt{\frac{.0491 \times 12}{\frac{1}{172} \times 56\left(1 + \frac{3.6}{12}\right)}} \quad V = 16{,}150 \text{ ft. per min.}$$

$$\frac{16150 \times .7854 \times 60}{172} = 7370 \text{ lbs.}$$

Had .2″ mercury been the greatest drop allowed

$$V = 13{,}700\sqrt{\frac{.2 \times .491 \times 12 \times 172}{56\left(1 + \frac{3.6}{12}\right)}} \quad V = 22{,}850$$

and 10,400 lbs. could be taken care of through the 12″ pipe.

FEED WATER HEATERS

Feed water heaters are of two classes, open heaters and closed heaters.

In an open heater the water can not be heated above 212° while in a closed heater higher temperatures than 212° are possible.

A primary heater is a heater placed on the exhaust pipe between the main engine or turbine and the condenser.

A secondary heater which may be either an open or a closed heater utilizes the heat of the auxiliaries, exhausting at atmospheric pressure, in raising the temperature of the water leaving the primary heater to a temperature within 8 or 10 degrees of that of the exhaust steam. From the secondary heater the water passes through the economizer (if one is used) to the boiler.

A feed water heater is very much like a surface condenser and consequently the same laws, regarding the interchange of heat per square foot of surface per degree difference of temperature, apply.

The interchange of heat in condensers was found to be proportional to the square root of the velocity of the water through the tubes. Feed water heaters designed for torpedo boats, etc., where space is very limited have been made with the water flowing at high velocity in the annular space between two tubes placed one inside the other. The high velocity of water gives a large interchange of heat but requires 8 or 10 lbs. additional pressure on the pump forcing the water through the heater.

The C. H. Wheeler Co. use the following formula in figuring the surface needed in a closed heater:

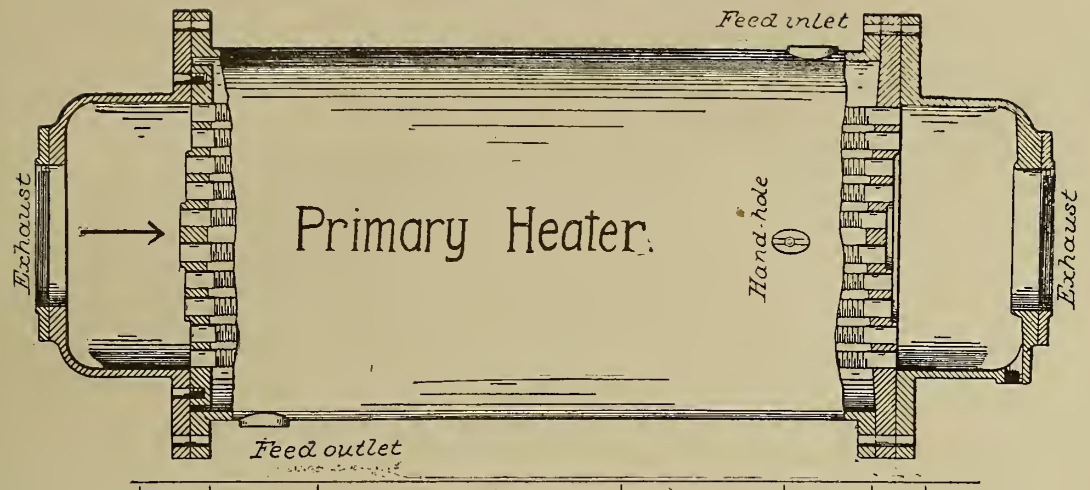
S = sq. ft. surface
W = lbs. of water per hour
t_s = temperature of steam °F.
t_c = temperature of cold water entering °F.
t_h = temperature of hot water leaving °F.
K = constant of transmission taken as 250

$$S \frac{W}{K} 2.3026 \log_{10} \frac{t_s - t_c}{t_s - t_h}$$

It is always safer to put in a larger heater than appears at first to be necessary.

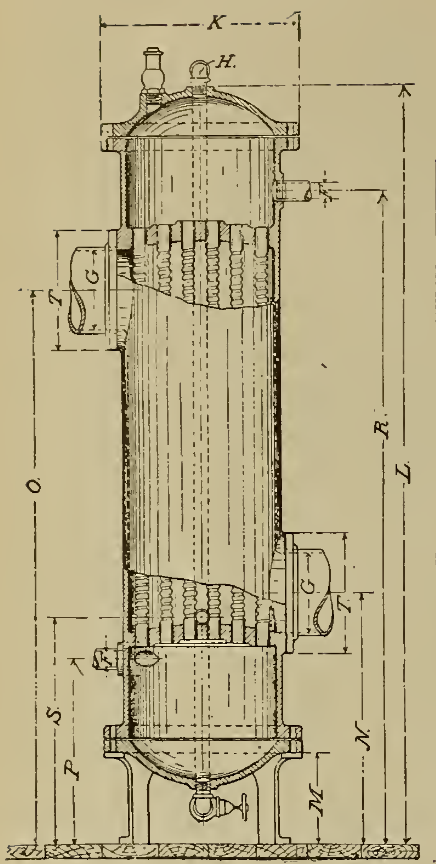
Tables of dimensions of both a Primary and a Secondary heater are given. These tables will give the general dimensions only.

The feed piping at a heater should be arranged so that in case of any trouble with the heater, the water can be by-passed around the heater. This necessitates three valves. The piping must be of brass in order to resist the action of the hot water.



Nominal ENGINE Horse Power.	SHELL.		TUBES.					PIPING.			Capacity in gallons at one filling.	Height over all.	Approximate Weight.
	Inside Diam.	Length.	Diam.	Number.	Length Each.	Total Length in feet.	Heating Surface in sq. ft.	Diam. Feed.	Diam. Exhaust.	Drips.			
30	12	20	1½	15	21	25	11.6	1	4	1	6.0	33	300
40	12	24	1½	15	25	31	14.3	1	4	1	9.8	39	435
50	14	28	1½	17	29	41	18.7	1	5	1	16.3	45	625
60	14	31	1½	17	32	45	20.7	1	5	1	18.0	48	700
75	14	38	1½	17	39	55	25.3	1	5	1	21.9	55	750
100	16	40	2	16	41	54	32.9	1½	6	1	28.0	58	875
150	16	56	2	16	57	76	46.0	1½	6	1	39.3	74	1000
200	20	44	2	28	45	105	63.4	2	8	1	45.6	67	1300
250	20	54	2	28	55	126	76.2	2	8	1	57.7	77	1650
300	25	45	2	40	46	152	92.0	2½	10	1½	76.8	72	1650
350	25	53	2	40	54	180	108.8	2½	10	1½	89.5	80	2450
400	30	48	2	50	49	204	123.3	2½	10	2	121.8	78	3470
500	30	58	2	50	59	245	147.0	3	12	2	147.8	88	3800
600	30	61	2	55	62	282	171.7	3	12	2	151.8	91	4000
700	34	58	2	68	59	333	201.5	3	12	2½	186.8	94	4750
800	34	68	2	68	69	391	236.4	4	12	2½	219.1	104	5000
900	34	75	2	68	76	420	254.0	4	15	2½	241.8	111	5300
1000	34	82	2	68	83	469	282.9	4	15	2½	264.2	118	5700

In computing the heating surface of the above table 15 per cent. is added for the corrugations.

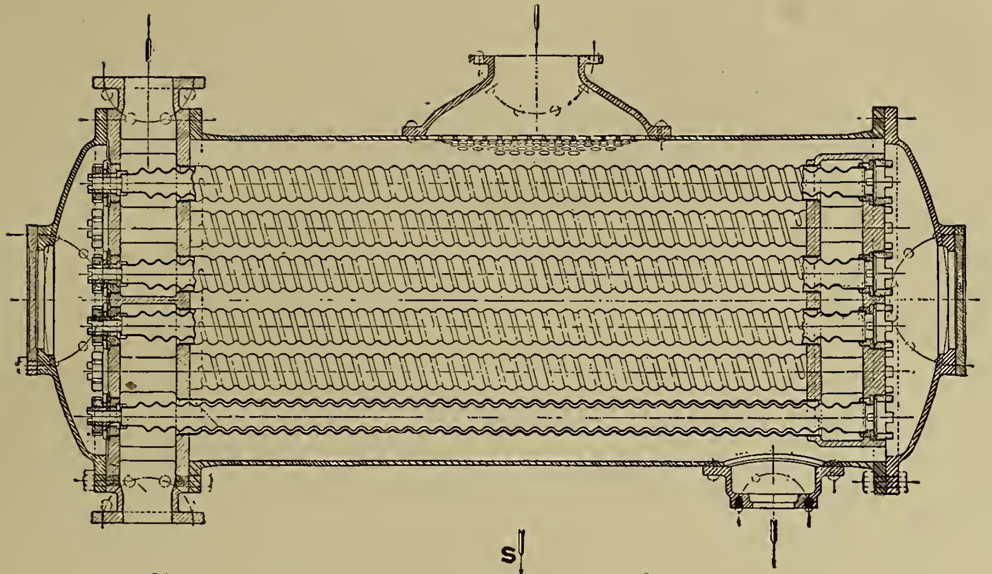


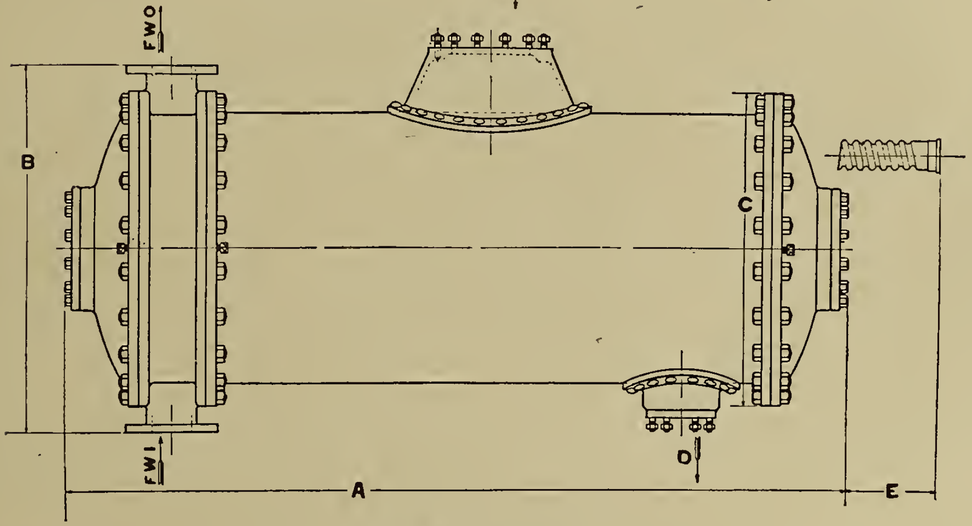
Secondary Heater.

Boiler HP	Inside Diam. Shell.	Number of Tubes.	Length of Tubes.	Outside Diam. Tubes.	Total Heating Surface, Allowing 15 per cent. for Corrugations	SIZES IN INCHES. F.	G.	H.	K.	L.	M.	N.	O.	P.	R.	S.	T.
25	10	9	26	1½	8.89	1	5	1	14¾	49	8	17¾	36¼	13¼	42½	15¾	10
50	12	12	37	1½	16.69	1½	6	1¼	16¾	63	8	19½	48¼	14	55¼	17¼	11
60	12	12	45	1½	20.30	1½	6	1¼	16¾	71	8	19½	56¼	14	63¼	17¼	11
80	12	12	60	1½	27.06	1½	6	1¼	16¾	86	8	19½	71¼	14	78¼	17¼	11
100	12	12	74	1½	33.38	1½	6	1¼	16¾	100	8	19½	85¼	14	92¼	17¼	11
150	15	24	60	1½	54.05	2	8	1¼	20	92	9	23¾	72¾	17	82¼	20½	13
200	18	36	50	1½	67.68	2½	10	1¼	23½	89	12	29½	65¾	21	77½	25	15
250	18	36	62	1½	83.91	2½	10	1¼	23½	101	12	29½	77¾	21	89½	25	15
300	18	36	74	1½	100.17	2½	10	1¼	23½	113	12	29½	89¾	21	101½	25	15
350	22	54	58	1½	117.77	2½	12	1½	27	104	14	34¾	77	24¾	90½	29½	18
400	22	54	66	1½	134.00	3	12	1½	27	112	14	34¾	85	24¾	98½	29½	18
500	24	63	72	1½	170.56	3	12	1½	30	122	16	40¼	92¾	27½	107	33	18
600	27	84	64	1½	202.14	3	14	2	34	121	18	43¾	87¼	31	104	37	21
700	27	84	74	1½	233.74	4	14	2	34	131	18	43¾	97¼	31	114	37	21
800	30	102	70	1½	268.48	4	14	2	38	133	20	49	95	34	114	41½	21
900	30	102	80	1½	306.85	4	14	2	38	143	20	49	105	34	124	41½	21
1000	32	114	78	1½	334.36	4	18	2	40	143	20	51	103	34	124	42½	26
1200	32	114	94	1½	402.97	5	18	2	40	159	20	51	119	34	140	42½	26
1500	36	144	93	1½	503.59	5	24	3	44	162	22	57	119	39	144	44	32
2000	36	144	124	1½	671.80	5	24	3	44	192	22	58	150	39	175	44	32
3000	48	258	104	1½	1008 96	6	30	3	56	181	24	66	130	43	160	48	38
4000	48	258	138	1½	1338.87	6	30	3	56	211	24	66	164	43	194	48	38
5000	60	402	111	1½	1677.99	8	30	3	68	202	26	72	143	47	175	52	38
6000	60	402	135	1½	2038.51	8	30	3	68	226	26	72	167	47	199	52	38

A type of feed water heater which has been recently developed by Shutte and Koerting Co. for use in battleships, torpedo boat destroyers and places where saving of space is an item, is shown by the sectional cut which follows.

In this type of heater, the water to be heated is sent through a narrow space between sets of corrugated tubes. The lower tube in the cut referred to shows one set of tubes in section. The steam which heats the water is on the outside of the larger corrugated tube and on the inside of the inner corrugated tube. The feed water is sent through these tubes under high velocity and, due to the fact that the water is broken up into a thin film, it is possible to heat it to within a very few degrees of the temperature of the steam. The loss in head in passing the water through the heater may be as great as 12 pounds. Dimensions of the different sizes of the heater, together with the horsepower rating may be obtained from the diagram and table which accompanies the same.





DIMENSION TABLE

Size No.	(Boiler Horse Power at 3# back Pressure	A	B	E	Feed Water Connections FWI FWO	Steam S	Drain D
1	80	5′ 1″	10½″	4′ 1½″	1″	2″	1″
2	160	5′ 1″	14″	4′ 1½″	1½″	3″	1″
3	330	5′ 1″	17″	4′ 1½″	1½″	3″	1¼″
4	500	5′ 3″	21″	4′ 2″	2″	4″	1½″
5	650	5′ 3″	22″	4′ 2″	2″	4″	1½″
6	830	5′ 3″	24″	4′ 2″	2″	4″	1½″
7	1000	5′ 5″	24″	4′ 2½″	3″	5″	2″
8	1150	5′ 5″	27″	4′ 2½″	3″	5″	2″
9	1300	5′ 5″	27″	4′ 2½″	3″	5″	2″
10	1500	5′ 7″	28″	4′ 3″	3½″	6″	2½″
11	1660	5′ 7″	28″	4′ 3″	3½″	6″	2½″
12	2000	5′ 7″	30″	4′ 3″	3½″	6″	2½″
13	2330	5′ 9″	33″	4′ 4″	4″	7″	3″
14	2700	5′ 9″	33″	4′ 4″	4″	7″	3″
15	3000	5′ 9″	36″	4′ 4″	4″	7″	3″
16	3300	5′ 11″	40″	4′ 5″	4½″	8″	3½″

COOLING TOWERS

The amount of water surface in a cooling tower working with forced air circulation varies from 23 to 27 square feet per I. H. P. More surface is needed in a natural draft tower than in a fan tower, in general the surface being double that of a forced draft tower. The amount of air needed depends to a large extent upon the humidity of the air entering the tower. The air leaving the tower is either saturated or nearly so.

It is not advisable to send an abnormal amount of air through a tower, as the cost of the increased power needed to run the fan and the greater shrinkage due to evaporation, amount to more than the gain made by the increased vacuum on the engine, resulting from the cooler circulating water, will offset.

The materials used inside of a cooling tower to expose as large a surface of cooling water as possible to contact with the air without at the same time obstructing the free flow of air, are tiers of the tile pipes 6″ diameter, 2 feet long, used by the Worthington Company, galvanized iron wire screens set nearly vertical, used by the Wheeler Company, galvanized iron troughs set horizontally and arranged so that the water flows from trough to trough as it descends (Jennison tower), boards, brush, or other material.

The amount of air to be supplied to a tower and the shrinkage of water from evaporation may be calculated approximately from the following equations:

Z = weight of cooling water entering condenser per lb. of steam.

E = weight of water evaporated from tower per lb. of steam condensed.

V_c = cu. ft. of cold air entering tower per lb. of steam condensed.

This air may enter by natural draft, or as is most often the case it may be sent in by disc fans.

V_h = cu. ft. of hot air leaving tower per lb. of steam condensed = $\frac{V_c T_h}{T_c}$

Y = the wt. of air entering the tower may be figured thus:

$$\frac{V_c}{\frac{29.92 \times 12.39}{491.5} \frac{T_c}{P_c}} = \frac{V_c}{.954 \frac{T_c}{P_c}}$$

T_c = absolute temperature of air entering.

P_c = absolute pressure of air entering tower in ins. of mercury.

If the excess pressure of the air entering the tower is measured by the difference of water level in a U-tube, P_c = the sum of the barometer reading and $\frac{.0365}{.491}$ times the difference of water level. This excess pressure can usually be neglected.

Q_h and Q_c are the heats of the liquid corresponding to the temperatures of the hot and cold condensing water.

Y_h and Y_c are the weights of water carried by a cu. ft. of saturated air at temperatures t_h and t_c respectively. See curves

$$Z \times (Q_h - Q_c) = \frac{V_c}{.754 \frac{T_c}{P_c}} \times .24\ (t_h - t_c) + r\ (.90 \times V_h\ Y_h - \text{relative humidity} \times V_c\ Y_c)$$

t_h and t_c are temperatures of air at top of tower and at entrance to tower. r is the heat of evaporation corresponding to the temperature of the air at top of the tower. The temperature of the air at the top of the tower is from 10 to 25 degrees lower than the temperature of the hot condensing water taken where it enters the tower.

In making a calculation for a tower it is probably safe to assume a difference of 15 degrees. The air leaving the tower may be saturated or only partially saturated, the condition depending upon the amount of air sent in and the design of the tower. In general it is a good plan to assume that the air at the top of the tower is only 90% saturated and that the temperature of this air is 15 degrees lower than the temperature of the hot water entering the tower. These assumptions have been made in the calculations which follow.

$$E = .90 \times V_h\ Y_h - \text{relative humidity} \times V_c\ Y_c$$

In the case of a jet condenser the steam condensed adds one pound to each Z pounds of cooling water entering the condenser.

If E is greater than one pound then the excess must be supplied as make-up water.

For a surface condenser E represents the make-up water.

Problem.

A cooling tower receives water from a surface condenser at 122° F., the water leaves the cooling tower at 90° F.; temperature of outside air 72°, relative humidity 80%.

Temperature of condensed steam 95°, vacuum in condenser 25″, barometer 29.7″.

Engine of 500 H. P. and consumes 20 pounds of steam per H. P.

What is the amount of air needed per pound of steam condensed and what is the per cent loss of cooling water due to evaporation?

$$\frac{1053.2 - 63.1}{90.0 - 58.1} = \frac{990.1}{31.9} = 31.8 = Z$$

$$990.1 = \frac{V_c}{\frac{.754 \times 531.5}{29.7}} \times .24 \left\{ (122 - 15) - 72 \right\} + 1031.8 \left\{ .9\ \frac{V_c \times 566.5 \times .00347}{531.5} - .8\ V_c \times .00124 \right\}$$

The figures .00347 and .00124 are the lbs. of water required to saturate a cu. ft. of dry air at 107 and at 72 deg. respectively. The figure 1031.8 is the value of the heat of vaporization at 107°.

$$990.1 = 3.036\ V_c \qquad V_c = 326 \text{ cu. ft.}$$

E = (.00333 − .00099) V_c = .763 lbs. evaporation per lb. of steam condensed or per 31.8 lbs. of circulating water.

This is $\frac{.763}{31.8}$ = .0240 or 2.40% shrinkage. As the first term of the right hand side of this equation evaluates $.623 V_c$ it is evident that the heat carried off by the air is $\frac{.623}{3.038}$ percentage of the total amount abstracted. This figures as 20.5%; the heat taken out by evaporation being 79.5%.

To illustrate more fully the use of the equation and to illustrate also the extra cost (at the cooling tower) of a high vacuum over a moderate vacuum, two cases will be taken up: First a condensing and cooling outfit maintaining a 28″ vacuum and, second, a similar outfit maintaining a 26″ vacuum.

The illustration will be worked through for each case with relative humidities of the entering air as 90, as 70, and as 50%

First case — A condenser maintaining a 28″ vacuum with hot condensing water at 95° or 7 degrees below the temperature corresponding to the vacuum. The exhaust steam is assumed to contain 4% of moisture. The temperature of the air may be taken as 72° and it will be assumed that the tower is to cool the water to this temperature.

For air 90% saturated at 72° the volume required per pound of steam = V_c may be calculated thus: To abstract the heat from a pound of exhaust steam 43.5 lbs. of cooling water would be the minimum weight required, since 1000 heat units are to be abstracted from each pound of steam with an increase in temperature in the circulating water of 23°.

$$1000 = \frac{V_c}{.754\,\frac{531.5}{29.92}} \times 24 \left\{ (95 - 15) - 72 \right\} + 1046.6 \left\{ .9\,\frac{V_c \times 539.5}{531.5} \times 0.0158 - .9\,V_c \times 0.0124 \right\}$$

$$1000 = .143\,V_c + 1046.6\,(.00144 - .00112)\,V_c$$

$$1000 = .143\,V_c + .335\,V_c \qquad V_c = 2100 \text{ cu. ft.}$$

The evaporation = .00032 × 2100 = .672 lbs.

Of this total heat abstracted the heating of the air accounts for 30 per cent and the evaporation 70 per cent.

Similar calculations for 70 per cent and for 50 per cent humidities give

Per cent humidity entering air	Cu. ft. air per lb. of exhaust	Evap. per lb. of exhaust condensed	Per cent heat abstracted by the air	Per cent heat abstracted by vaporization
90	2090	.672	30	70.0
70	1350	.770	19.4	80.6
50	990	.812	14.1	85.9

Second: Suppose that the vacuum to be carried is 26″ with air at 72° and hot condensing water at 119° or 7 degrees below the temperature corresponding to the vacuum. Cold water at 72°; and 4 per cent moisture in the exhaust steam.

The heat to be abstracted per pound of exhaust is 983 B. T. U. and 20.9 lbs. of cooling water is the minimum required per pound of exhaust. From calculations similar to the preceding it appears that the amounts of air needed and the evaporations are:

Relative humidity	Cu. ft. air	Evaporation in pounds	Per cent heat abstracted by the air	Per cent heat abstracted by vaporization
90	386	.737	22.5	77.5
70	350	.756	20.8	79.2
50	321	.773	18.7	81.2

The amount of water evaporated per pound of *steam condensed* is about the same in each case.

In the first case with 70 per cent humidity the evaporation was .770 in 43.5 lbs. of water sent into the tower, or 1.8%.

In the second case with 70 per cent humidity about 3.6%.

The curve showing the pounds of water needed to saturate one pound of air at any temperature may be constructed very quickly from values taken from any steam tables.

Example.— The amount of water required to saturate one cubic foot of air at 88° F. is .002 lb. If the air was of a relative humidity of 60 to start with, then 40 × .002 would be the amount the air would take up in becoming saturated and the B. T. U. abstracted would be

$$1042.2 \times .40 \times .002 = .834 \text{ per cu. ft. of air.}$$

PER CENT OF ENGINE POWER REQUIRED BY COOLING TOWER FAN AND BY THE EXTRA DISCHARGE HEAD ON THE CIRCULATING WATER

Referring to the first case already cited, with relative humidity of 70, 1350 cu. ft. of air were needed. Suppose a disc fan is to be used and a dynamic head of .3″ of water maintained at the fan. As the static head is zero the velocity head will be .3″.

This velocity pressure corresponds at 70° to a velocity of 2200 ft. per minute. Suppose the engine uses 14 pounds of steam per H. P. per hour, then the steam per minute is 14/60 lbs. and the cu. ft. of air sent through the tower is 14/60 × 1350.

The H. P. input to the fan is, for this case, if 30 per cent is assumed as fan efficiency:

$$\text{H. P.} = \frac{.3'' \times 5.2 \times 14/60 \times 1350}{33000 \times .30} = .0498 \text{ or } 5.0\%$$

of engine power.

To this should be added the power due to pumping 14/60 × 43.5 pounds of cooling water per minute through an additional head of about 30 feet. This amounts to .00889 H. P.

If the fan were driven by a small engine using 35 pounds of steam per H. P. hour and the circulating apparatus were also steam driven using 40 lbs. per H. P. hour, then the extra steam required by the cooling tower outfit would be

$$.050 \times 35 + .0089 \times 40 = 2.10 \text{ and } \frac{2.10}{14} = .15 \text{ or } 15.0 \text{ per cent additional.}$$

A similar calculation for the second case with 26°″ vacuum, 70% humidity with engine using 15 pounds of steam per H. P. hour gives:

$$\text{Air per minute} = \frac{15}{60} \times 350$$

$$\text{H. P. to fan} = \frac{.3 \times 5.2 \times \frac{15}{60} \times 350}{33000 \times .30} = .0137$$

$$\text{Extra H. P. on circulating pump} = \frac{20.9 \times \frac{15}{60} \times 30}{33000} = .00472$$

If fan engine and circulating apparatus were steam driven then using same rate as before

$$.0137 \times 35 + .00472 \times 40 = .668$$

$$\frac{.668}{15} = .0445 \text{ or about } 4.45\% \text{ additional.}$$

If the cooling surface used in the tower offers much resistance to the free discharge of air from the fan through the tower, it may be necessary to run the fan at higher velocity which increases the work of driving.

In the Wheeler Barnard cooling tower the cooling surface consists of galvanized wire screens placed in parallel vertical rows about 3″ apart. Water is distributed to the tops of these screens by U-shaped troughs each trough supplying two screens. In this way as each side of a screen is figured as cooling surface, 8 sq. ft. of surface is obtained per cubic foot of volume in the screen section of the tower. But little resistance is offered to the passage of air between the screens.

From experiments made by the company it is found that ordinarily eleven feet of vertical length of screen offers sufficient evaporating surface to saturate the air. The tower is square or rectangular in section and the number of fans needed depends upon the size of the tower.

The B. T. U. per hour per square foot of surface in a cooling tower apparently varies from 200 to 900.

It is not possible to get figures for a square foot of surface which will apply to every type of tower since with different kinds of surface there is a variable amount of spraying; even with the same surface this spraying varies with the quantity of water flowing; and consequently there is available an unknown amount of surface besides that provided in the tower.

A drop of water .178″ in diameter weighs .75 grains and the surface of a number of drops sufficient to make a gallon would be about 54 square feet.

Cooling towers are occasionally placed on the roof of buildings. By using a surface condenser the extra work on the up leg of the circulating water is practically offset by the gain from the down leg and there is simply the friction in the extra lengths of piping to make additional work for the circulating pump.

Where one tower is used for a number of condensers having centrifugal circulating pumps it is advisable to have a separate discharge pipe from each centrifugal to the tower.

Towers cost above the foundation from $2.60 to $4.00 per K. W. capacity.

SPRAY NOZZLES

By spraying water into the air a cooling may be effected through the evaporation of a part of the water just as was the case in the cooling tower.

The total exposed surface of the sprayed jet meets less air per pound than in the cooling tower, and on this account it is often advisable to spray 30 to 50 per cent of the water a second time before sending it through the condenser.

Generally spray nozzles of the size known as 2″ are the most economical. The 2″ size screws on to a 2″ outlet; the opening in the nozzle tip being about .8″. As many nozzles should be provided as are needed to discharge the entire weight of condensing water under a pressure of not over 15 lbs. gage at the nozzle.

The nozzles should be set from 8 to 10 feet apart if 2″; a greater distance if over 2″. Where a considerable number of nozzles are used it is customary to have the water which is sprayed into the air fall back into an artificial pond one or two feet deep. When a number of nozzles are in use the aspirator action exerted by the jets causes a current of air to flow along the surface of the pond from the edge towards the centre. This current of air assists to some extent in the cooling.

In some few instances spray nozzles have been put along the edges of a narrow brook and the falling spray caught on board fences inclined 30° with the ground and draining into the brook.

There are one or two small plants where the cooling nozzles discharge on to the roof of the building. From tests made in the Engineering Laboratories of the Massachusetts Institute of Technology on the Schutte Koerting nozzles it seems that

1° The temperature of the water after spraying is more dependent upon the temperature and humidity of the atmosphere and upon the fineness of the spray than upon the initial temperature of the water. Therefore it is advisable to spray the water as hot as may be without excessive steaming.

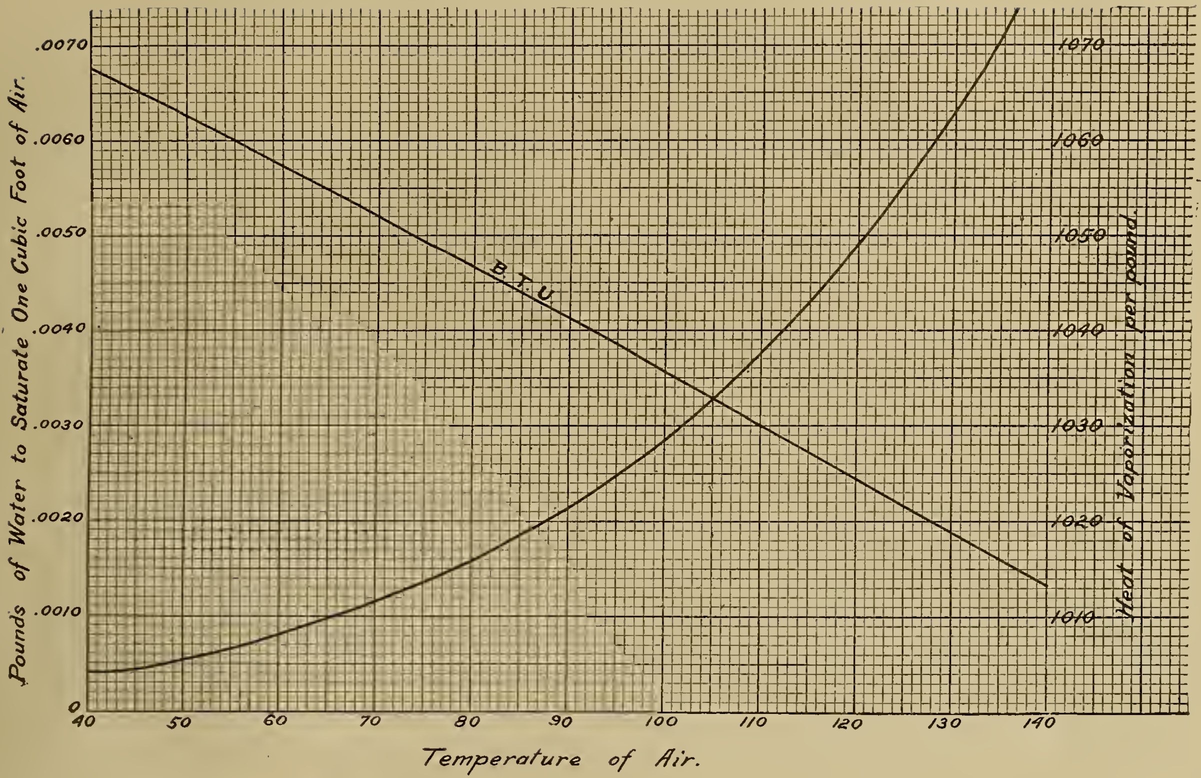
2° At high humidity, 80% or 90%, the temperature of the water may be lowered to within 12° F. or 13° F. of the temperature of the air, with a total drop in temperature of 35° F. to 40° F.

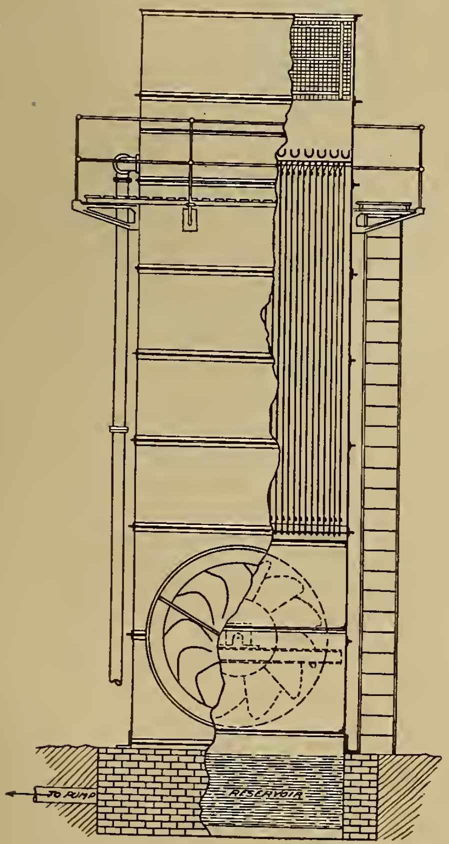
3° At low humidity 20% to 30%, the temperature of the water after spraying may be as much as 8° F. below the temperature of the air and the total drop in temperature 40° F. to 45° F.

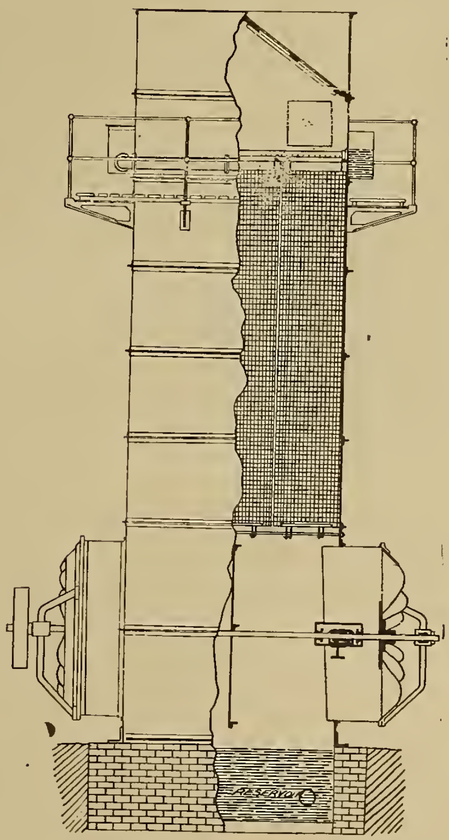
4° The loss of water by evaporation is approximately .15 pounds per degree lowering of temperature per 100 pounds of water discharged, or a gross loss of about 6% for 40° F. lowering of temperature. In no case was the loss found to exceed 7%.

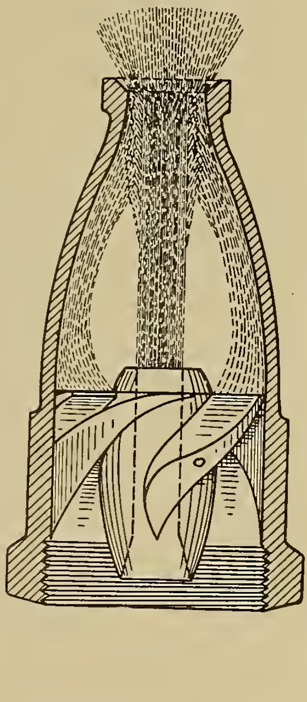
The discharge of these nozzles was found to be as follows:

Head in ft. at base of nozzle.	Cu. ft. per min. for 1″ pipe. Diam. nozzle at tip .406″	Cu. ft. per min. for 2″ pipe Tip = .800″ diam.	Cu. ft. per min. for 3″ pipe Tip = 1.181″ diam.
25	1.782	6.736	14.83
30	1.952	7.379	16.24
35	2.109	7.971	17.54
40	2.254	8.521	18.75
45	2.391	9.036	19.89
50	2.520	9.526	20.97
55	2.643	9.991	21.99
60	2.761	10.44	22.97
65	2.873	10.86	23.91


Pounds of Water to Saturate One Cubic Foot of Air.
.0070
.0060
.0050
.0040
.0030
.0020
.0010
0
B.T.U.
1070
1060
1050
1040
1030
1020
1010
Heat of Vaporization per pound.
40
50
60
70
80
90
100
110
120
130
140
Temperature of Air.


TO PUMP
RESERVOIR


RESERVOIR



CENTRIFUGAL PUMPS

Centrifugal pumps either single or multistage are replacing the reciprocating piston pump for pumping condensate, circulating water and feed water.

Centrifugal pumps should have the impeller designed for the conditions of suction head, delivery head, speed and capacity the pump is to work under. Well designed pumps give efficiencies of from 75 to 80 per cent.

The centrifugal pumps of five stages used in the high pressure fire service in the City of New York showed under test efficiencies of 75 and 77 per cent when working with delivery pressures of 300 lbs.

Centrifugals are sometimes arranged so that two pumps driven by the same shaft may deliver into a common discharge, thus giving a large quantity at a moderate pressure; or the discharge of one may be sent into the suction of the other and the delivery pressure increased; the quantity of water being, of course, decreased.

If the efficiency of each pump is 71 per cent the efficiency of the outfit used either way will remain practically the same.

In pumping circulating water from a jet condenser to a cooling tower, as there is less than atmospheric pressure on the suction side of the pump, the total static head should be calculated from the difference of the absolute pressures at entrance to and exit from the pump. To this head expressed in feet should be added an amount sufficient to allow for the friction and other losses.

The efficiency of the smaller pumps is probably not over 60 per cent.

The velocity of water in the discharge pipe should not exceed 400 feet per minute; 6 feet a second is a velocity quite commonly allowed.

Although a number of centrifugal pumps connected to jet condensers may work successfully when piped to a common discharge leading to a cooling tower, it is always safer to connect each centrifugal with the tower through a separate pipe.

Turbine driven stage centrifugals are quite generally used now in the large boiler plants in place of the steam or power driven reciprocating feed pump. The hot feed water must come to the pump under a head. The efficiency of centrifugals used as feed pumps may be assumed to be between 40 and 55 per cent; 45 per cent has been used as the efficiency in the calculation for horse power input given below.

The maximum horse power input required by a centrifugal boiler feed pump is

$$\text{Centrifugal Feed Pump H. P. input} = \frac{2.32 \times \text{Gage Pressure} \times 30 \times \text{Max. Boiler H. P.}}{33{,}000 \times 60 \times .45}$$

$$= \frac{7.8 \times \text{Gage Pressure} \times \text{Max. Boiler H. P.}}{100{,}000} \text{ approx.}$$

Centrifugal pumps have to be primed (filled with water) before starting. This may be done by putting a foot valve on the end of the suction pipe and then filling with water under pressure, the air at the top of the casing being vented, or the pump may be primed by closing a valve in the delivery pipe and then exhausting air from the top of the pump casing by a steam ejector, a water ejector or by means of a connection to a dry vacuum pump.

As a foot valve offers considerable resistance to the flow of water it is to be avoided whenever possible; should it be necessary to use a foot valve one at least two sizes larger than the suction pipe is to be recommended.

Centrifugal pumps of large capacity either turbine driven or motor driven have been used as pumping units in municipal pumping stations. While it is not possible to get as high a duty as may be obtained with a reciprocating pump the first cost is only about one third that of the reciprocating and the number of operatives required to run the centrifugal outfit is less.

These pumps should have both a check valve and a hydraulically operated discharge valve in the discharge pipe. In shutting the pump down the discharge valve is closed before the power is shut off. While the pump might be stopped without closing this valve and the check valve depended upon to prevent a flow-back from the reservoir or standpipe, should this valve stick open and close suddenly the water hammer blow resulting could not be withstood by the pump or the piping.

Pumps used for this service should have suitable characteristics. The pressure should not build up over 15 per cent when the discharge valve is closed with the pump running.

Following are some characteristic curves obtained from test data on different types of pumps. All of these curves were plotted for a constant speed. The pumps would have different characteristic curves at every speed. These curves were plotted at the most economical speed of the unit.

Fig. 1 shows the curves taken from a Worthington Tri-rotor pump. This pump was connected to an 800 H. P. Curtis Turbine and installed for the Carnegie Steel Company for pumping dirty water. This pump has no discharge valves and gives an efficiency of 74% which is high for a volute pump.

Fig. 2 gives the curves of a DeLaval pump which are notable in that the power taken by the pump decreases rapidly after the point of maximum efficiency is reached. This allows of the installation of a motor which is just capable of handling the full load of the pump.

Fig. 3 shows the characteristic curves for a Worthington Boiler Feed Pump installed at the Commonwealth Edison Company. The pump is of the double suction type in which water is admitted to both sides of the impeller. This pump has three stages and is connected to a 150 H. P. Curtis Turbine running at 2350 R. P. M. The feature of the characteristics is the wide range of discharge over which the efficiency is high.

Fig. 4. The set of curves was taken from a double stage Alberger Fire Pump which runs at a speed of 1400 R. P. M. and requires a 90 H. P. motor. The high efficiency of this pump is notable for a double stage pump. These curves also show what would take place if the discharge piping should fail while the pump was in operation. The head would, of course, fall nearly to zero and the discharge would go up rapidly. The horse power taken from the motor under these conditions would increase rapidly due to the marked decrease in efficiency. In this set of curves the power supplied would be 107 at zero head and hence the 90 H.P. motor must be capable of sustaining this overload of 17 H. P. for a short time.

All centrifugal pumps operating under suction head must be primed before they can be started. All the passages of the pump must be completely filled with water before the pump will "pick up." It is dangerous in many cases to allow a pump to be started without priming, since many pumps are so constructed that they depend on the presence of water for running balance and interference at the clearance spaces may destroy the pump if water is not present.

The theory of centrifugal pumps with reference to the blade angles, calculation of pressures in the casing, and other points of design, is extremely complicated and based entirely on assumptions as to existing conditions in the pump.

The entrance angle of the impeller depends upon what assumptions are made in regard to the direction of absolute velocity at entrance. This velocity is usually assumed to be radial, and is taken as 15 feet per second for pumps without lift and 10 feet per second for pumps with lift.

The construction of the blade is arbitrary to some extent. Some manufacturers use the arc of a circle, others an involute, and still others a logarithmic spiral.

In the accompanying print α represents the angle of entrance of the impeller and θ the angle of entrance to the guide vanes. The effect of the shape of the blades on the exit and entrance velocity diagrams is also shown in the print.

The De Laval centrifugal is made with the angle at exit 20° with the tangent.

In order to estimate the loss of head through friction in piping the accompanying chart taken from the catalogue of the De Laval Co. is quite convenient to use.

If the quantity of water passing through the pipe and the size of the pipe are known, the friction head in 1000 feet length of pipe is found by laying a straight edge through the known points of the scales representing capacity and size of pipe. The friction head is then read off on the third scale at the point of intersection between the straight edge and this scale.

The values obtained from this chart are based upon the Hazen-Williams formula:

$$v = cr^{0.63}\left(\frac{h}{l}\right)^{0.54} \times 10^{0.12}$$

where v is the velocity in feet per second, r is the hydraulic radius $= \frac{\text{diameter}}{4}$ in feet, h the friction head and l the length of piping. c is a constant depending upon the roughness of the pipe and upon the hydraulic radius.

The formula can also be written

$$h = \left(\frac{147.85}{c} \times \frac{Q}{d^{2.63}}\right)^{1.852}$$

where h is, as before, the friction head in feet for $l = 1000$ ft., Q is the water quantity in gallons per minute and d is the diameter of pipe in inches.

The chart is based upon a value of $c = 100$, which is mostly used and considered safe for ordinary conditions.

For other value of c the figure obtained from the chart should be multiplied by $K = \left(\frac{100}{c}\right)^{1.852}$

For information regarding coefficient c for different kinds and size of pipes, and also value of K for different values of c, see table below.

Size of Pipe, inches			2 to 3	4	5	6	8	10	12	16	20	24	30	36	42	48	54	60
c	K	Condition of pipe	Year of Service for Cast Iron Pipe															
140	.54	Very smooth and straight and Brass, Tin, etc.		00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
130	.615	Ordinary straight Brass or Tin		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
120	.715	Smooth new Iron		4	4	4	5	5	5	5	5	5	6	6	6	6	6	6
110	.84						10	10	10	11	11	11	12	12	12	12	12	12
100	1.0	Ordinary Iron•		13	14	15	16	17	17	18	19	19	19	20	20	20	20	20
90	1.21								26	27	28	29	30	30	30	30	31	31
80	1.51	Old Iron		26	28	30	33	35	37	39	41	42	43	44	45	45	46	47
60	2.58	Very rough		45	50	55	62	68										
40	5.45	Badly tuberculated		75	87	95												

00 indicates the very best cast iron pipe laid perfectly straight, and when new.
0 indicates good new cast iron pipe.

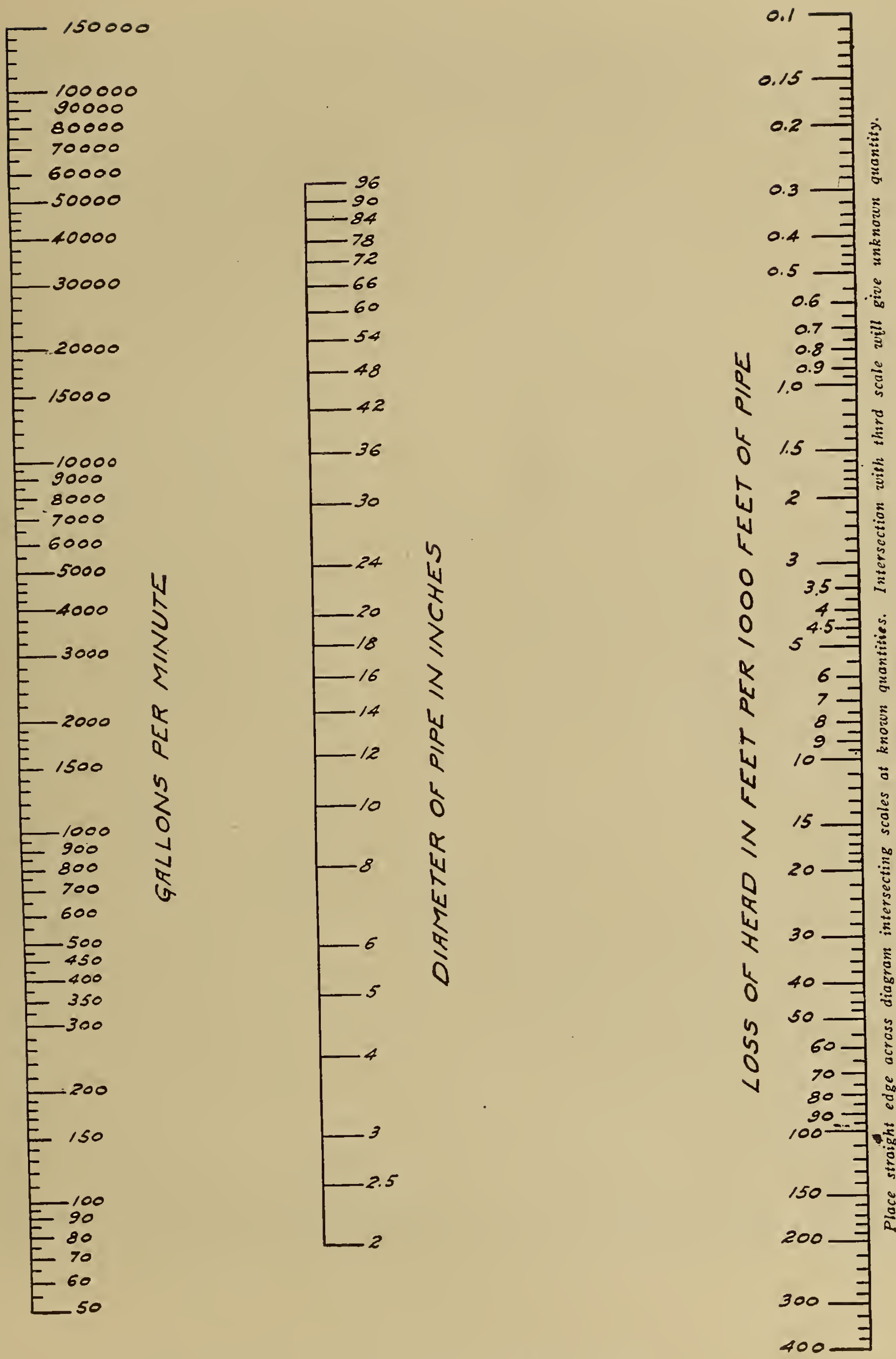
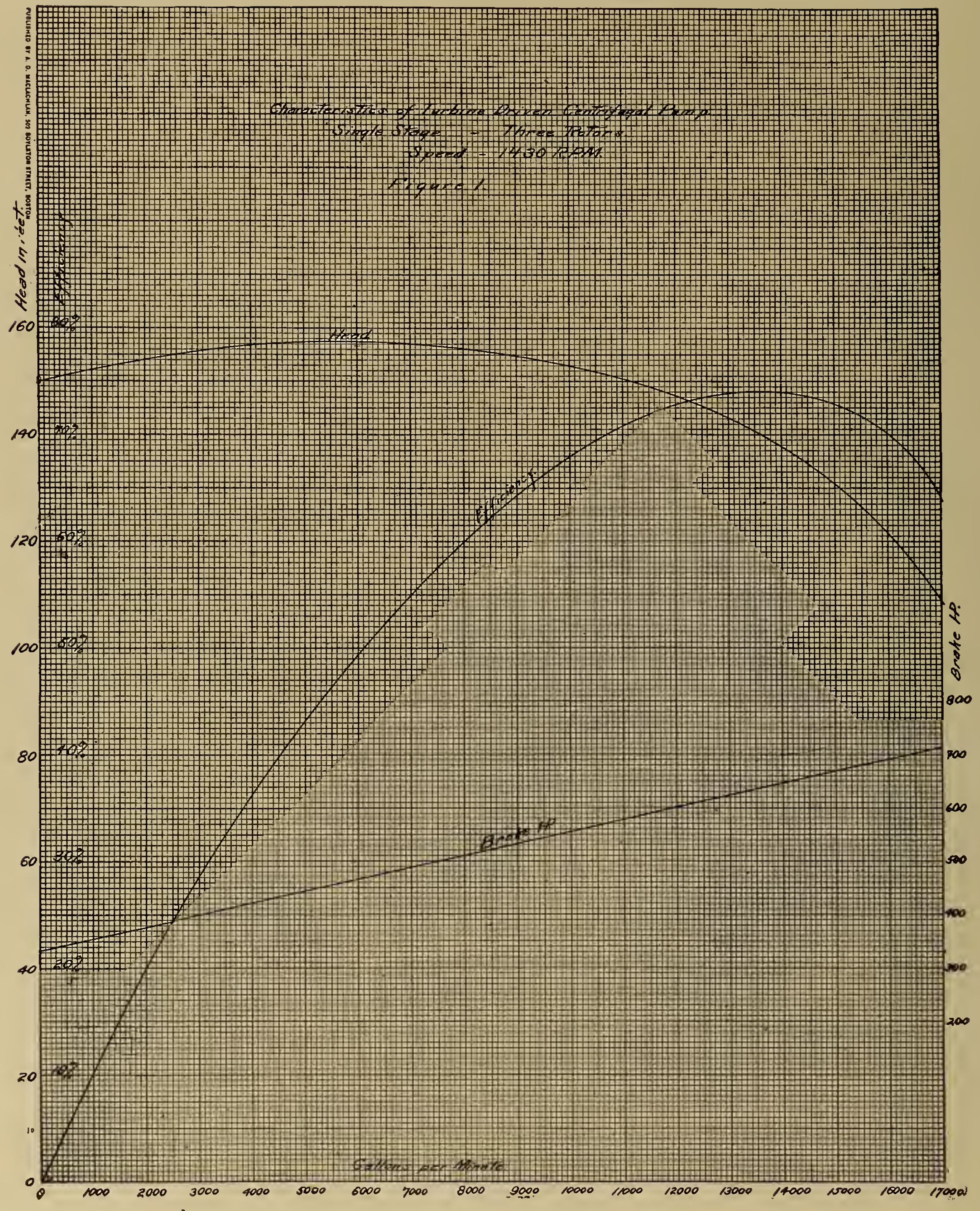


Chart for determining resistance of pipes to flow of water.


Characteristics of Turbine Driven Centrifugal Pump
Single Stage - Three Rotors
Speed - 1430 RPM
Figure 1.
Head in Feet
Efficiency
Head
Efficiency
Brake H.P.
Brake H.P.
Gallons per Minute
160
140
120
100
80
60
40
20
0
80%
70%
60%
50%
40%
30%
20%
10%
800
700
600
500
400
300
200
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
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12000
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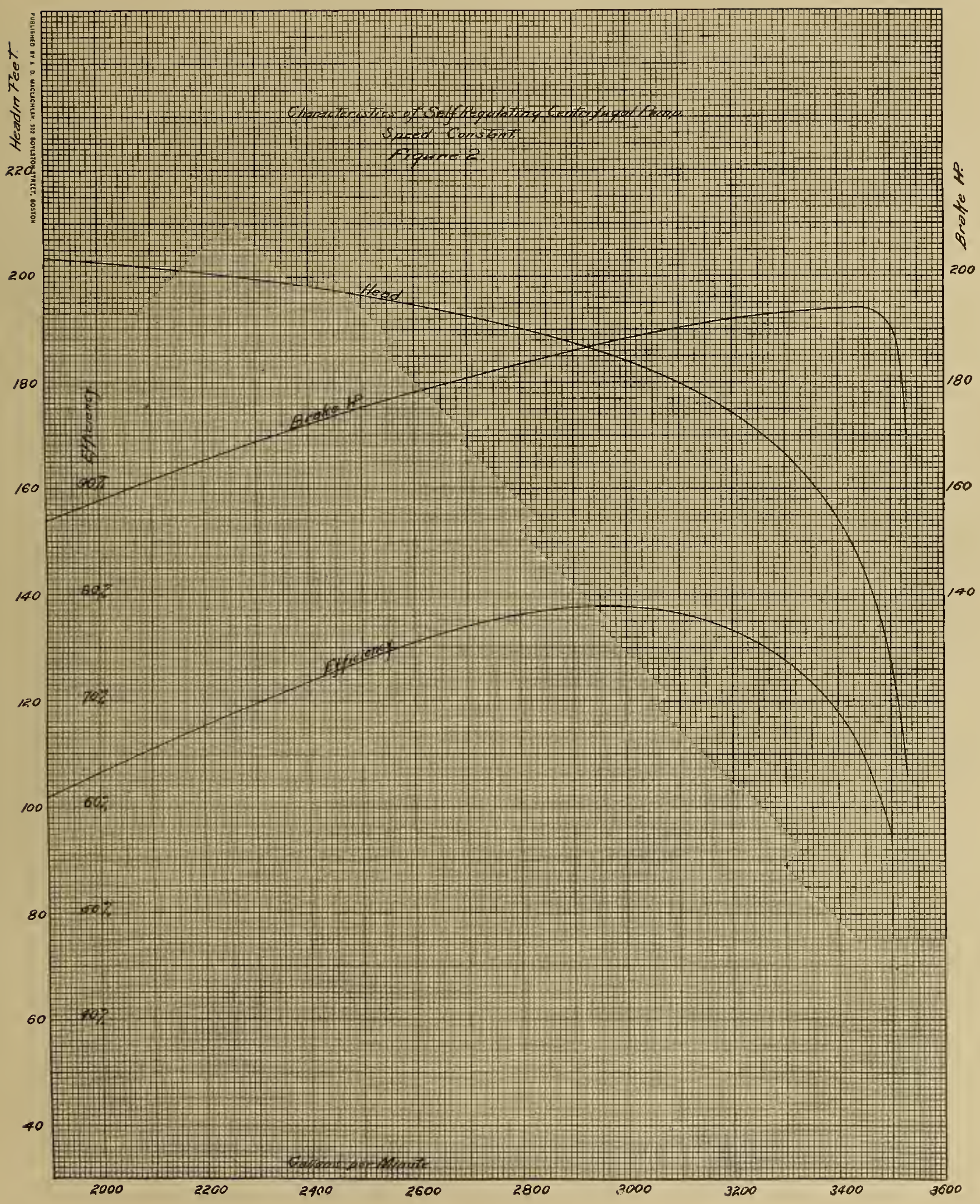
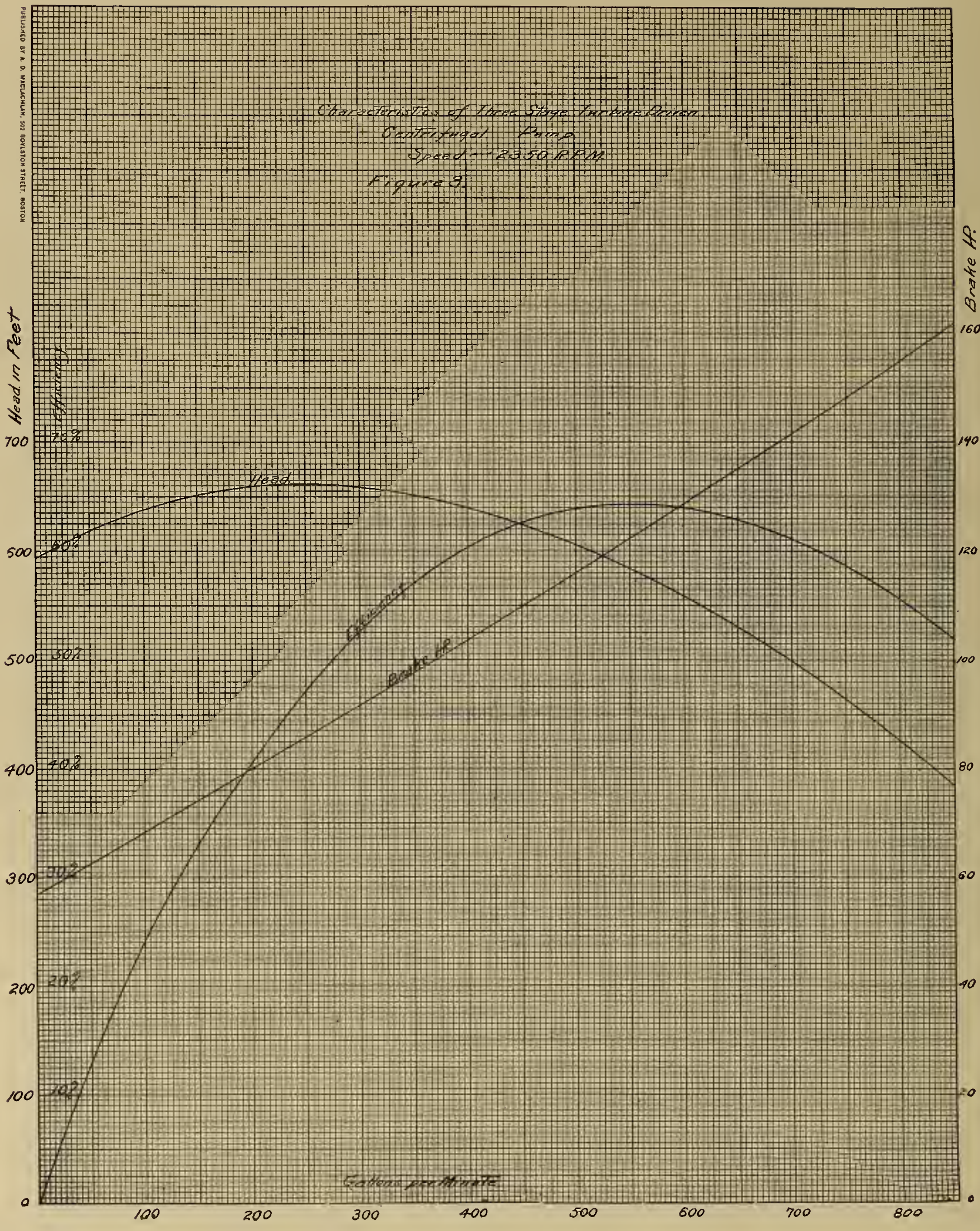
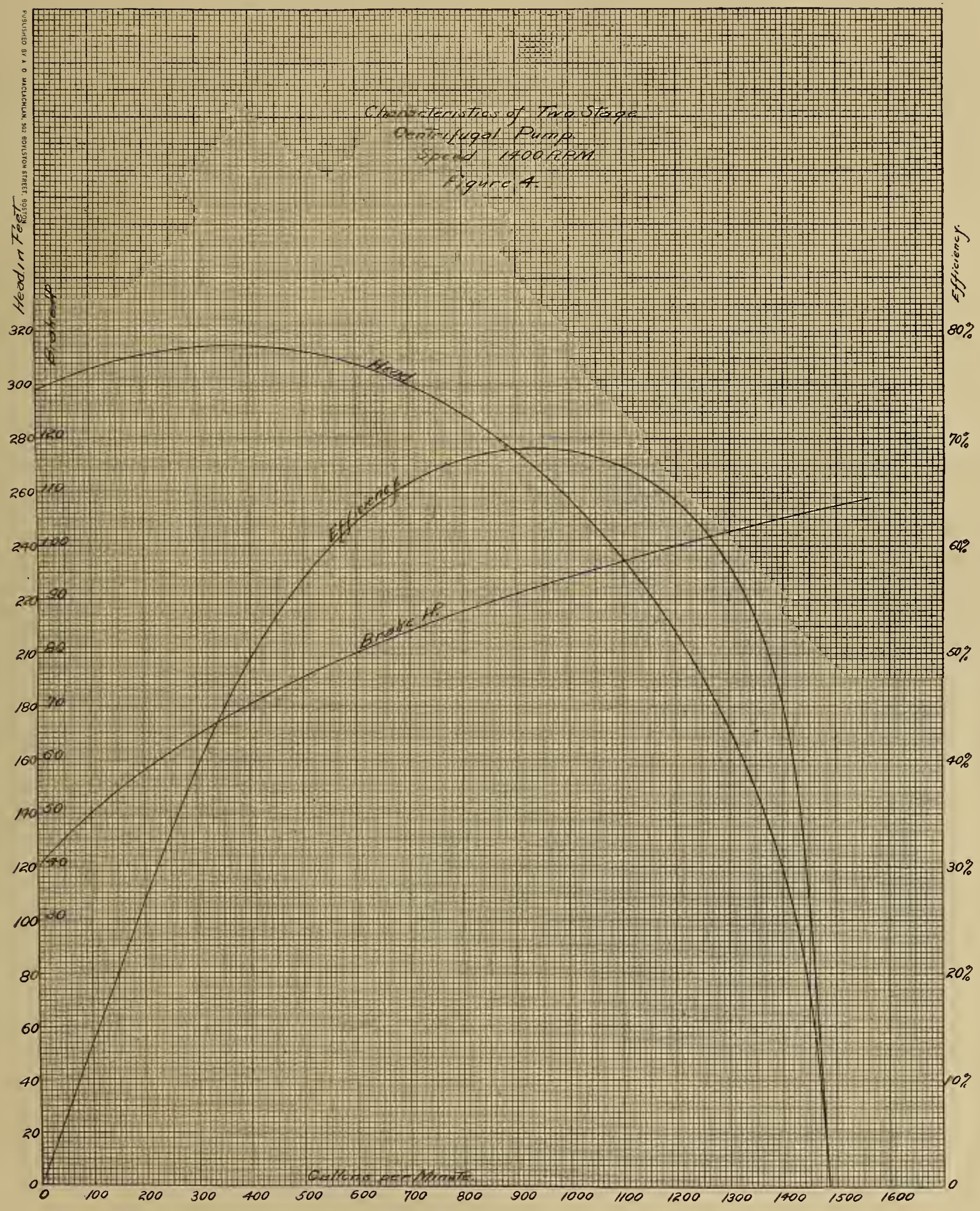
14000
15000
16000
17000


Characteristics of Self Regulating Centrifugal Pump
Speed Constant
Figure 2.
Head in Feet
Brake H.P.
Head
Brake H.P.
Efficiency
Efficiency
90%
80%
70%
60%
50%
40%
220
200
180
160
140
120
100
80
60
40
200
180
160
140
Gallons per Minute
2000
2200
2400
2600
2800
3000
3200
3400
3600

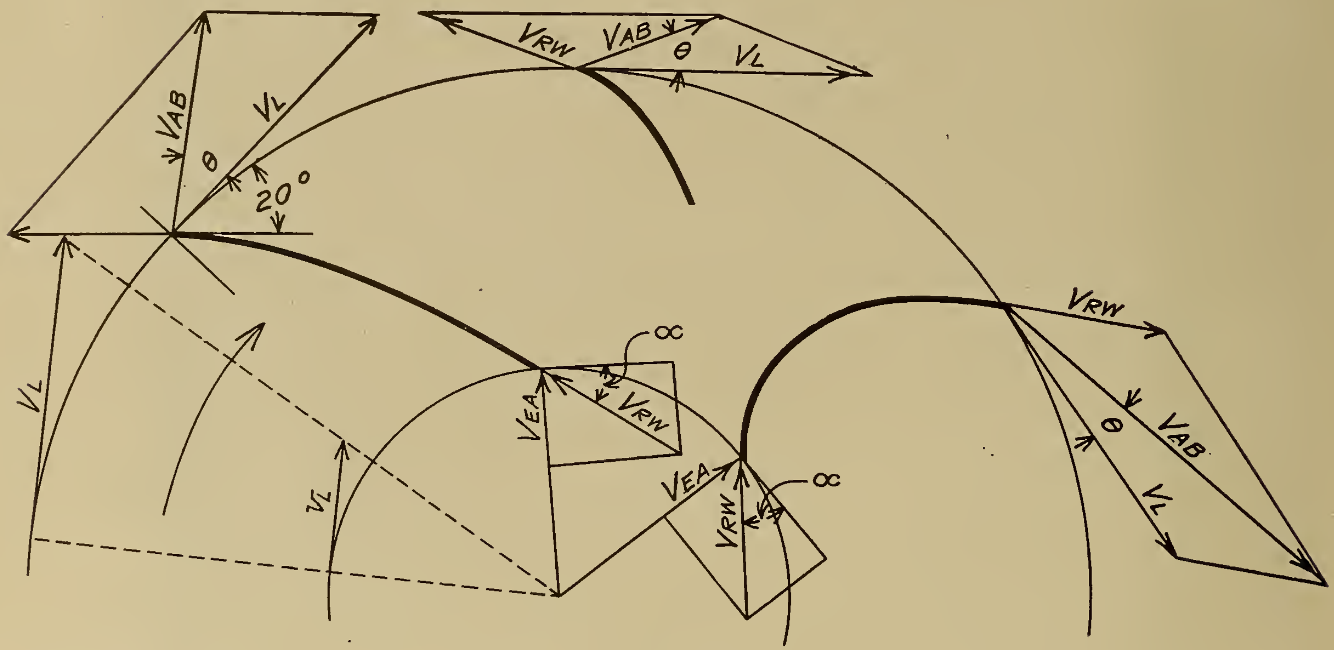

Characteristics of Three Stage Turbine Driven
Centrifugal Pump
Speed—2350 R.P.M.
Figure 3.
Head in Feet
Efficiency
Brake H.P.
Head
Efficiency
Brake H.P.
Gallons per Minute
700
400
300
200
100
0
70%
40%
30%
20%
10%
100
200
300
400
500
600
700
800
160
140
120
100
80
60
40
0



Characteristics of Two Stage
Centrifugal Pump
Speed 1400 R.P.M.
Figure 4.
Head in Feet
Brake H.P.
Efficiency
Head
Efficiency
Brake H.P.
Gallons per Minute
320
300
280
260
240
220
210
180
160
140
120
100
80
60
40
20
0
120
110
100
90
80
70
60
50
40
30
80%
70%
60%
50%
40%
30%
20%
10%
0
0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600

V_L = Linear velocity of impeller at outer edge.
v_L = " " " " inner " .
V_{EA} = Absolute velocity at entrance (Taken radial).
V_{RW} = Velocity of water relative to wheel.
V_{AB} = Absolute exit velocity from impeller.

Radial velocity at entrance is usually taken at 15 f.p.s. if there is no lift and 10 f.p.s. if there is a lift.



COAL HANDLING, COAL BUNKERS

FLIGHT CONVEYORS

One of the oldest forms which, from its simplicity and comparatively low first cost, is still one of the most extensively used, consists merely of an endless chain to which are attached, at intervals, scrapers or flights. The improved forms of this conveyor, now most generally used, have sliding shoes or rollers attached to the flights or the chains, supported on runways. The flights are allowed to come very close to the trough bottom, but not actually in contact with it, thus reducing the friction upon the trough to the minimum amount.

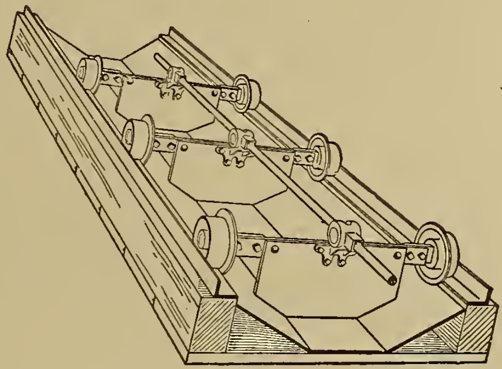
The accompanying figure illustrates a single-strand flight conveyor.

CONVEYING CAPACITIES ON FLIGHT CONVEYORS

S. R. Peck, A. S. M. E., 1910

In tons (2000 pounds) of coal per hour at 100 feet per minute.

Size of Flight	Horizontal Spaced			Lbs. per Flight	Inclined		
	18 Inches	18 Inches	24 Inches		10° 24 Inches	20° 24 Inches	30° 24 Inches
4 x 10	33¾	30	22½	15	18	14¼	10½
4 x 12	42¾	38	28½	19	24	18	13½
5 x 12	51¾	46	34½	23	28½	22½	16½
5 x 15	69¾	62	46½	31	40½	31½	22½
6 x 18		80	60	40	49½	40½	31½
8 x 18		120	90	60	72	57	48
8 x 20			105	70	84	66½	56
8 x 24			135	90	120	96	72
10 x 24			172½	115	150	120	90



The horse-power required for handling anthracite coal may be determined from the following formula, this taking no account of gearing or other driving connections.

$$H.P. = \frac{ATL + BWS}{1000}$$

T = net tons per hour.
L = length, centre to centre, in feet.
W = weight of chain and flights (both runs) in pounds.
S = speed per minute in feet.

A and *B* are constants depending on the inclination from the horizontal. (See value below.)

	Hor.	5°	10°	15°	20°	25°	30°	35°	40°	45°
A	0.343	0.42	0.50	0.585	0.66	0.73	0.79	0.85	0.90	0.945
B	0.01	0.01	0.01	0.01	0.009	0.009	0.009	0.008	0.008	0.007

The common working speeds are from 100 to 200 feet per minute, and the capacities are as shown by the table, these conveyors in some cases handling upwards of 500 tons per hour.

As an illustration, suppose it is desired to elevate hard coal 50 feet by a flight conveyor inclined 30 degrees, the capacity of the conveyor being 30 tons per hour at 100 feet speed per minute. From the table it is evident that at a speed of 100 feet per minute the flight should be 6 inches by 18 inches and spaced 24 inches apart.

The length of the conveyor, centre to centre, would be at least 100 feet.

Calling the weight of the chain 20 pounds per foot, and the weight of the flights spaced every 2 feet, 40 pounds, as given, the total weight per foot figures as 40 pounds.

Substituting, in the formula given, the

$$\text{H. P.} = \frac{0.79 \times 30 \times 100) + (0.009 \times 200 \times 40 \times 100)}{1000}$$

$$= 7.77$$

PIVOTED BUCKET CARRIERS

Where the design of the plant requires conveying machinery adapted to the combined service of handling coal and ashes, the pivot-bucket carrier is hard to excel. The handling of ashes is very hard on conveying machinery, and the construction of the carrier permits replacement of the several parts as corrosion or wear proceeds.

Pivoted-bucket carriers for elevating coal in power-plant service have become quite popular. Their advantages are slow speed, silent operation, adaptability to change of direction without transfer, high efficiency, and easy renewal of worn parts. Their disadvantages are danger of buckets sticking or upsetting and jamming in the supports, and the difficulty of preventing spill at the loading and turning points. Protection against jamming may be had by connecting with the driving machinery through a safety pin whose margin of strength beyond the power requirements is very slight; or better, by designing the supports so that the buckets will clear in whatever position they may come around.

Uncleanly loading is guarded against in various ways in the several latest designs of carriers, of which the following may be noted.

In the Hunt carrier, the buckets are spaced an inch or so apart and are loaded by a special device consisting of a series of connected funnels at the loading chute, in synchronism with, and dipping into, the carrier buckets, so that each bucket receives its proper charge only.

The Webster carrier has buckets with carefully planed lips, the pitch of the buckets being very slightly less than the pitch of the carrier chain links, thus depending on close contact to eliminate the leakage.

The McCaslin carrier uses overlapping buckets. These lap the wrong way after tripping for discharge, and are reversed by a "righting mechanism" before again passing the loading point.

The Peck carrier uses overlapping buckets similar to the McCaslin, but they are attached to the links extended beyond the points of articulation. This arrangement unlatches the buckets at the turns by giving them a path of greater radius than the chain joints, thereby doing away with a righting device otherwise necessary with the overlapping bucket.

None of these devices for preventing spill at the loading and turning points are particularly effective. The difficulty is inherent in this type of conveyor whose many advantages, however, far outweigh their defects.

The alternative of the pivoted-bucket carrier for handling coal is the standard arrangement of an elevator with rigid steel buckets discharging into a flight conveyor which crosses above the bunkers, and is provided with discharge gates at convenient intervals; or instead of a flight conveyor, a belt with movable tripper. This is a well tried-out system, thoroughly reliable, and by many preferred to the run-around carrier, on the ground of lower first cost and simpler construction. The elevator conveyor system is not adapted to handling ashes, which, however, should be taken care of by separate machinery whenever possible to do so.

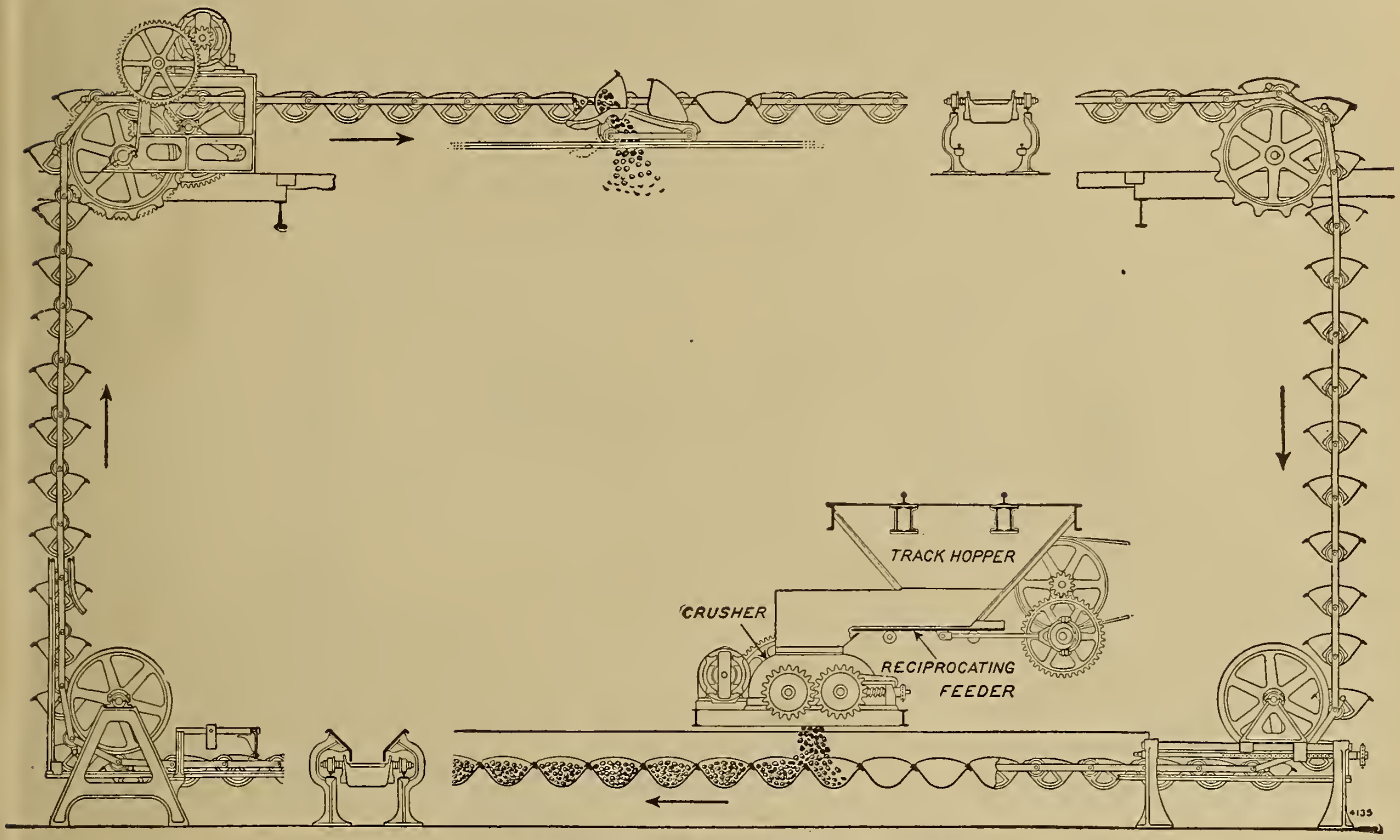


Diagram Showing Operation of the Peck Carrier

The general arrangement of a "rectangular" pivoted bucket conveyor is shown by the accompanying cut.

Coal discharged from a car or from a cart falls into a crusher where the large lumps are broken up. From the crusher the coal is taken directly into the conveyor or into the feeding mechanism which fills the conveyor.

Somewhere in the system there must be a tightener, which in this cut is shown as located at the lower right-hand corner.

The reciprocating feeder consists simply of a movable plate, at the bottom of the hopper, which is pushed forward and back through the action of an eccentric. On the forward stroke coal is fed into the crusher. The length of the plate is such that coal in the hopper will not flow over the left-hand edge when the feeding plate is still.

When coal is discharged directly through the track hopper, feeder and crusher into the conveyor buckets as shown in the cut, the track must be from 10 to 12 feet above the bottom run of the conveyor.

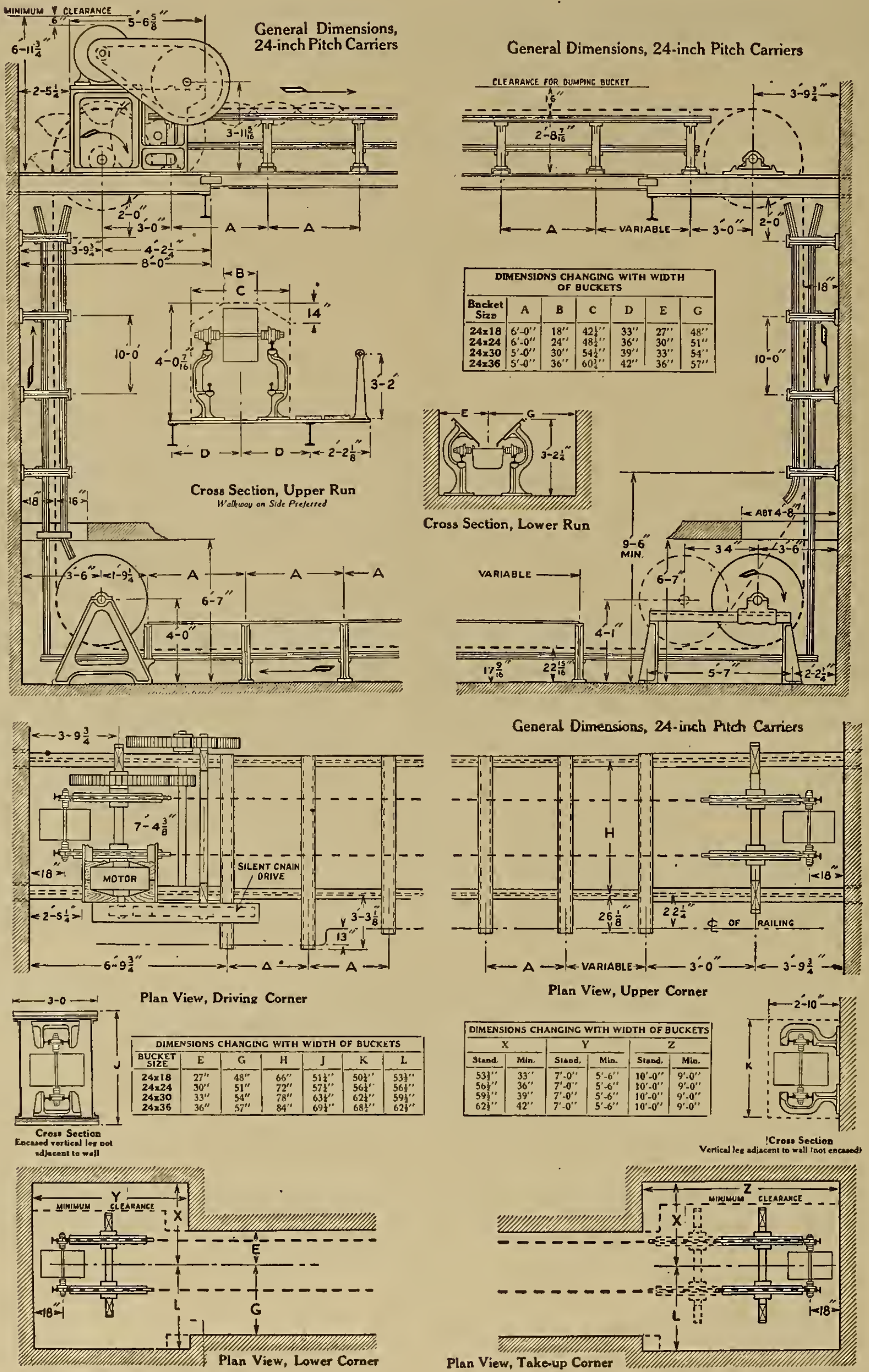
Where there is not sufficient depth for this arrangement an apron feeder (see illustration) would be used to elevate the coal to the crusher.

The speed of the apron must be regulated to suit the capacity of the carrier or a reciprocating feeder may be inserted between the hopper and the apron.

STANDARD SIZES AND CAPACITIES OF PECK CARRIERS

For a speed of from 40 to 50 feet per minute with pitch of chain 24 inches the capacity is

with buckets	24″ x 18″	40 to 50 tons coal per hour
with buckets	24″ x 24″	55 to 70 tons coal per hour
with buckets	24″ x 30″	75 to 100 tons coal per hour
with buckets	24″ x 36″	90 to 120 tons coal per hour



DIMENSIONS CHANGING WITH WIDTH OF BUCKETS

Bucket Size	A	B	C	D	E	G
24x18	6′-0″	18″	42¼″	33″	27″	48″
24x24	6′-0″	24″	48¼″	36″	30″	51″
24x30	5′-0″	30″	54¼″	39″	33″	54″
24x36	5′-0″	36″	60¼″	42″	36″	57″

DIMENSIONS CHANGING WITH WIDTH OF BUCKETS

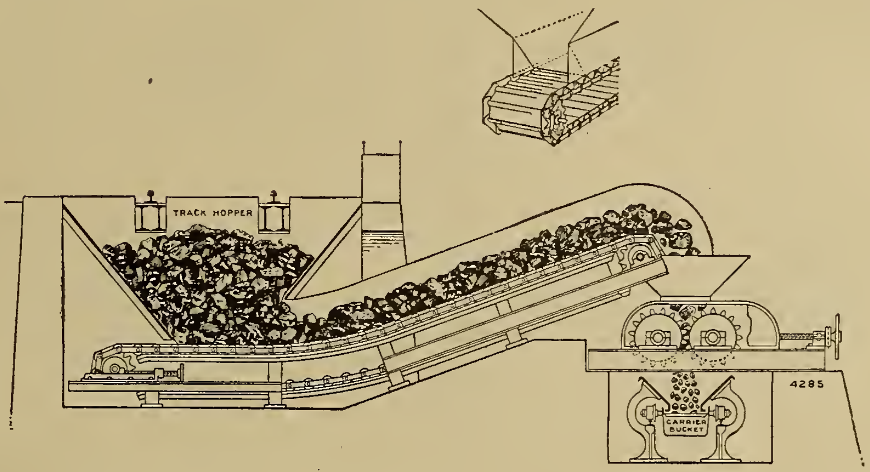
BUCKET SIZE	E	G	H	J	K	L
24x18	27″	48″	66″	51½″	50¼″	53½″
24x24	30″	51″	72″	57½″	56¼″	56½″
24x30	33″	54″	78″	63½″	62¼″	59½″
24x36	36″	57″	84″	69½″	68¼″	62½″

DIMENSIONS CHANGING WITH WIDTH OF BUCKETS

X		Y		Z	
Stand.	Min.	Stand.	Min.	Stand.	Min.
53½″	33″	7′-0″	5′-6″	10′-0″	9′-0″
56½″	36″	7′-0″	5′-6″	10′-0″	9′-0″
59½″	39″	7′-0″	5′-6″	10′-0″	9′-0″
62½″	42″	7′-0″	5′-6″	10′-0″	9′-0″

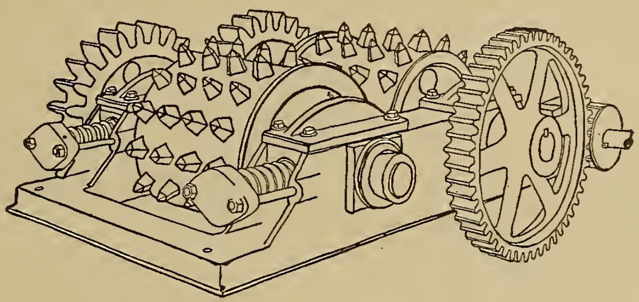
The general dimensions of a Peck carrier 24″ pitch may be obtained from the cuts shown on the preceeding page.

The power required for driving a rectangular conveyor similar to those referred to may be obtained from the following formula which is based on tests made on a number of such conveyors. H. P. = .000085 × tons per hour × speed in feet per minute × elevation in feet. The power running empty is approximately one-half of the power for loaded condition. The power required for an apron feeder may be calculated from the same formula. A reciprocating feeder requires about 5 H. P.



A coal crusher of 30 tons capacity per hour requires a floor space of 7′ × 4′-6″ and height of 3 feet overall when set on a cast iron base and 2 feet when set as shown in the cut illustrating the apron feeder. It requires 5 H. P. to drive it.

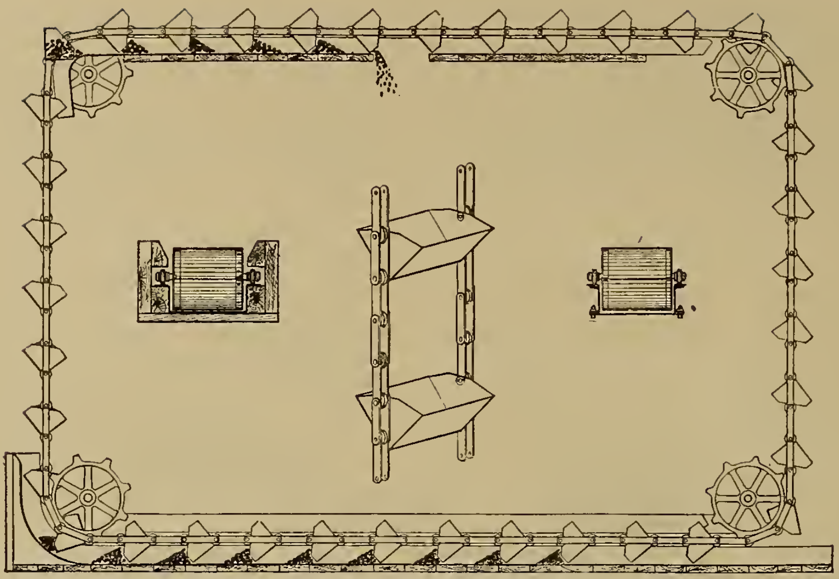
A 50 ton crusher 10 H. P. with floor space 9′ x 5′ and heights of 3′ 6″ and 2′ 6″ according to setting.

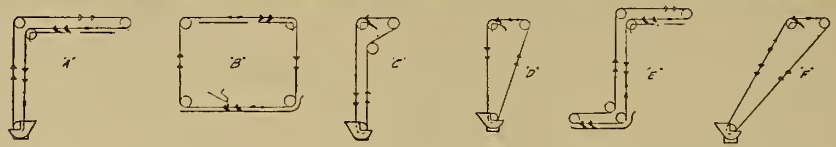


A 70 ton crusher 15 H. P. space 9′ x 6′ and heights of 4′ 6″ and 3′ 6″.

The accompanying cut shows a crusher with hopper and casing removed.

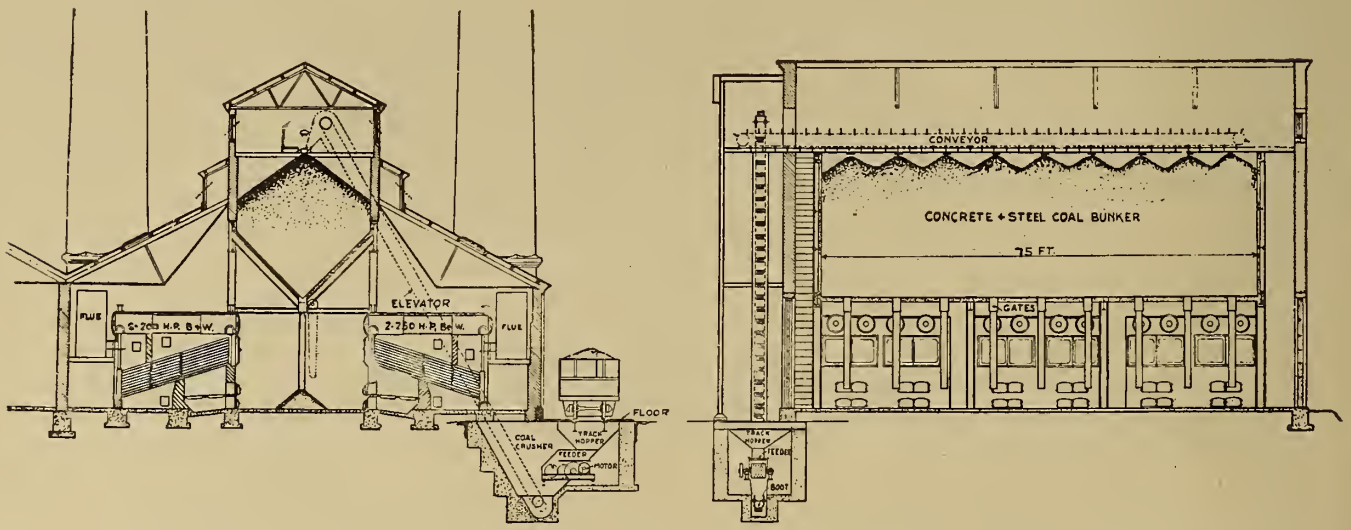
A *V* bucket elevator conveyor is shown by the sketch on the page following. The small diagrams *A-F* indicate some of the possible arrangements.





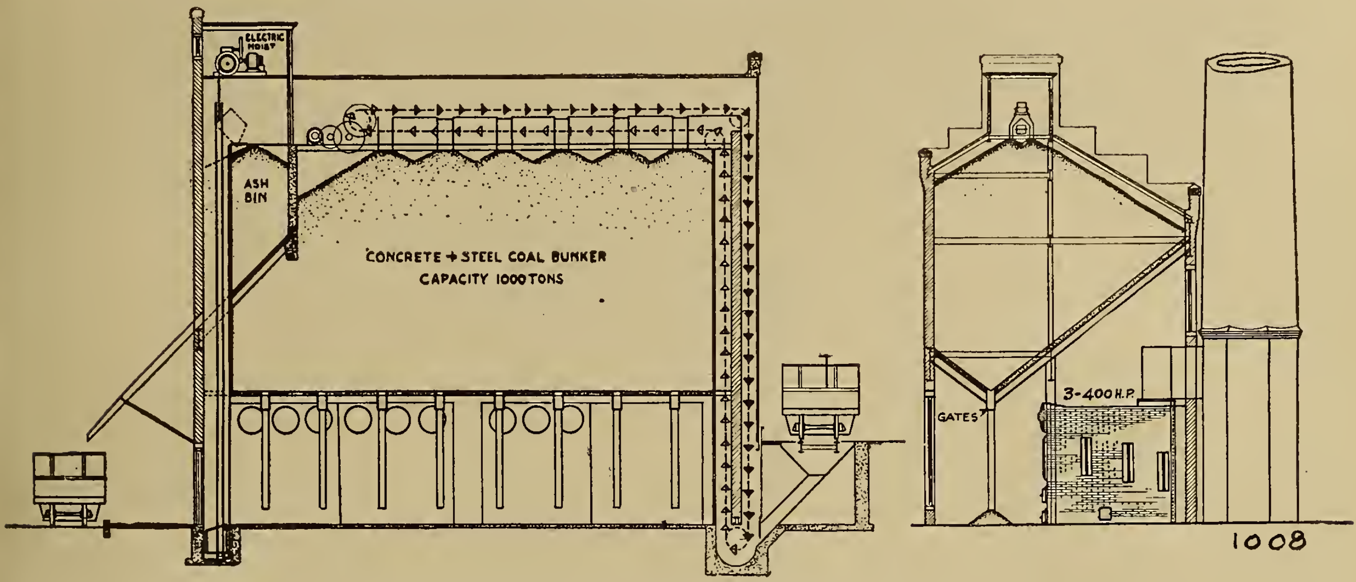
Coal is fed to the lower run by a plain chute, is then pushed along the run till the vertical is reached, where the coal is carried inside the buckets; on the upper run the coal is pushed along until it reaches an opening through which it is discharged.

A 40 ton *V* bucket elevator installed at the Bergner and Engel Brewing Co.'s plant and a 40 ton coal elevator and flight conveyor at the U. S. Arsenal at Frankford are shown by the cuts which follow.

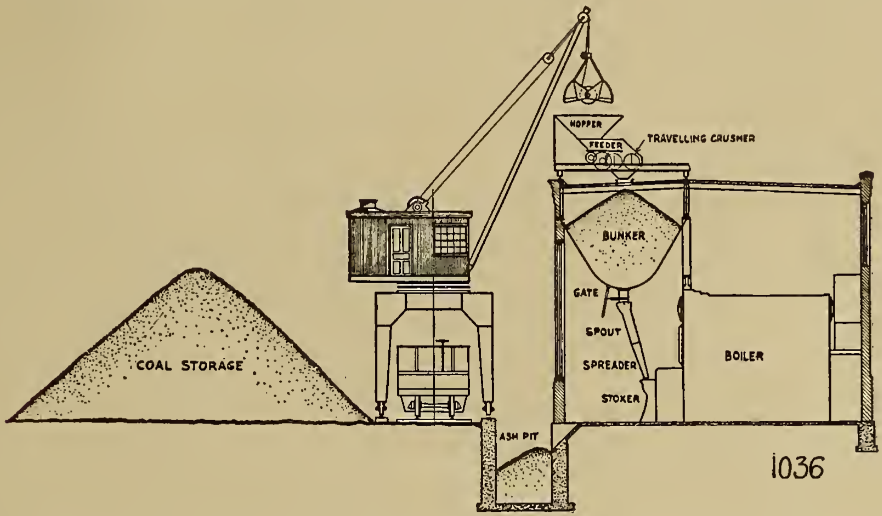


U. S. ARSENAL, FRANKFORD, PHILA.

A locomotive crane operating a grab bucket is frequently used to move coal from a storage pile onto a belt or bucket conveyor, for unloading barges, etc.



BERGNER AND ENGEL BREWING CO., PHILADELPHIA, PA.
40 ton per hour v-bucket elevator. Conveyor for coal; push car and electric skip for ashes.



Such cranes are either mounted on a car like a platform car or elevated as shown by the accompanying figure.

For unloading barges and hoisting coal to an elevator a tower known as the Boston tower is quite generally used. This handling device consists of a grab bucket operated from the tower, which has projecting out a distance of 20 or 30 feet, a horizontal arm on which travels a movable carriage through which run the hoisting ropes operating the grab bucket. This carriage may be moved out or in while the grab is being raised or lowered.

BELT CONVEYORS

If coal is to be conveyed any considerable distance a belt conveyor would be used. Belt conveyors will carry coal at an angle as great as 20° and may be built to handle any quantity of coal.

The following table gives the capacity, maximum size of lumps, and advisable speed for the different widths of belts.

BELT CAPACITY AND SPEED

Width of Belt.	Maximum Size of Pieces.	Maximum Advisable Speed in Feet per Minute.	Capacity in Cubic Feet at the Maximum Advisable Belt Speed.
12	2	300	1380
14	2½	300	1890
16	3	300	2460
18	4	350	3640
20	5	350	4480
22	6	400	6200
24	8	400	7400
26	9	450	9810
28	12	450	11250
30	14	450	13050
32	15	500	16500
34	16	500	18500
36	18	500	21000
38	19	550	25300
40	20	550	28050
42	20	550	30800
44	22	600	37200
46	22	600	40800
48	24	600	44400

When the quantity to be conveyed is small, and the pieces large, the size of the material fixes the width of the belt, and the speed should be as low as possible to carry safely the desired load.

When the quantity is great, the capacity fixes the width, and in this case also, the speed should be as low as possible. A belt at slow speed may be loaded more deeply than one at high speed, and when a narrow belt is run much above the advisable speed, the load thins out and the capacity does not increase as the speed.

The maximum length of the different widths of conveyors is determined by the fibre stress in the belt, and is, therefore, closely related to the load and speed. Naturally level conveyors may be built longer than those lifting material. Conveyors 1000 feet from centre to centre, handling 400 tons per hour, have been most satisfactorily operated.

Another important factor in the design of conveyors operated at high speed and handling large quantities is the flow of material in the chutes. A 36-inch conveyor handling 750 tons of coal per hour, with a belt speed of 750 feet per minute under a 10,000 ton pocket, could not be loaded from a single chute, because it was not possible for the coal to attain a speed of 750 feet per minute in the chute. It was necessary, therefore, in order to obtain a full load, to open seven gates, each placing a layer of coal on the belt until the desired load was obtained. During a test this belt carried about 800 tons per hour.

POWER REQUIRED FOR BELT CONVEYORS

The power required to drive a belt conveyor depends on a great variety of conditions, such as the spacing of idlers, type of drive, thickness of belt, etc.

In figuring the power required, it is important to remember that the belt should be run no faster than is required to carry the desired load. If for any reason it is necessary to increase the speed, the figure taken for load should be increased in proportion and the power figured accordingly. In other words, the power should always be figured for the full capacity at the chosen speed, as follows:

C = power constant from table.
T = load in tons per hour.
L = length of conveyor between centres in feet.
H = vertical height in feet that material is lifted.
S = belt speed in feet per minute.
B = width of belt in inches.

For level conveyors,

$$\text{H. P.} = \frac{C \times T \times L}{1000}$$

For inclined conveyors,

$$\text{H. P.} = \frac{C \times T \times L}{1000} + \frac{T \times H}{1000}$$

Add for each movable or fixed tripper horse-power in column 3 of table below.
Add 20 per cent to horse-power for each conveyor under 50 feet in length.
Add 10 per cent to horse-power for each conveyor between 50 feet and 100 feet in length.
The above figures do not include gear friction, should the conveyor be driven by gears.

POWER REQUIRED FOR GIVEN LOAD

Width of Belt.	1 C For Material Weighing from 25 lbs. to 75 lbs. per Cu. ft.	2 C For Material Weighing from 75 lbs. to 125 lbs. per Cu. ft.	3 H. P. Required for Each Movable or Fixed Tripper	4 Minimum Plies of Belt.	Maximum Plies of Belt.
12	.234	.147	⅓	3	4
14	.226	.143	½	3	4
16	.220	.140	¾	4	5
18	.209	.138	1	4	5
20	.205	.136	1¼	4	6
22	.199	.133	1½	5	6
24	.195	.131	1¾	5	7
26	.187	.127	2	5	7
28	.175	.121	2¼	5	8
30	.167	.117	2½	6	8
32	.163	.115	2¾	6	9
34	.161	.114	3	6	10
36	.157	.112	3¼	6	10

With the load and size of material known, choose from the capacity table the proper width of belt and proper speed. The above formulae give the horse-power required for the conveyor when handling the given load at the proper speed. With the horse-power and the speed known, the stress in the belt should be figured by the following formula in order to find the proper number of plies.

$$\text{Stress in belt in pounds per inch of width} = \frac{\text{H. P.} \times 33000}{S \times B}$$

With this value known, the number of plies may be determined, using 20 pounds per inch per ply as the maximum. Columns 4 and 5 of this table give the maximum and minimum advisable plies of the different widths of belt. Belts between these limits will trough properly and will be stiff enough to support the load.

Belt conveyors may be driven from either end. Somewhere in the system there must be a tightener to allow for the stretch of the belt. The troughing idlers should be placed dependent upon the weight of material carried as follows:

For belts 12 to 16 inches wide, from 4½ to 5 feet apart;
For belts 18 to 22 inches wide, from 4 to 4½ feet apart;
For belts 24 to 30 inches wide, from 3½ to 4 feet apart, and
For belts 30 to 36 inches wide, from 3 to 3½ feet apart.

The life of the belt depends a great deal upon the care which it receives, upon the material handled, and upon the quality of the belt to begin with. In general the life of the belt may be taken as from three to eight years.

THE DARLEY CONVEYOR

A system for handling coal or ash by a current of air flowing in a pipe has been in use in some plants during the last three years. A description of a system arranged for handling ash will show the method of operation. A pipe is laid under the floor in front of the boilers with an opening through the floor into the pipe in front of each ash-pit door, each opening being closed unless ash is being hauled from the ash-pit into it. The end of the pipe under the floor is open to the air. The other end of this pipe connects with a riser which leads up to the top of a closed steel storage tank in which the ash is to be stored. An exhaust fan or a Root exhauster draws air out of the tank, thus creating a flow in the pipe in front of the boilers. Any ashes, clinker, or even bricks dumped in through the holes in front of the boilers will be carried along by the air and delivered into the closed tank elevated 20 to 40 feet above the boilers. After the exhauster has been stopped the ashes may be discharged from this tank into a car or cart by opening an ash valve in the bottom.

To quench the hot ash and to prevent dust from being drawn over into the exhauster, a jet of water is sent in on the ash as it is entering the closed tank.

The fittings, especially those at the corners where the direction changes wear rapidly. The elbows are made with renewable chilled backs or in some cases a tee is used in place of an elbow. The plugged end of the tee filling up with ash causes the wear to come on the ash.

COAL BUNKERS

Coal bunkers may be of the cylindrical type with conical bottom; of the parabolic type made either of steel plate lined or unlined with concrete or of suspended steel straps with reinforced concrete carrying the load between the straps, of the structural steel type carried on girders running either parallel with the boiler fronts or on cross girders at right angles to the boiler fronts; the steel being protected by a reinforced concrete lining.

It is difficult to make a calculation of the stresses in the girders supporting a coal bunker, 1st, on account of the unequal and variable loading and 2nd, because the coal may act like a dry sand under certain conditions and again under other conditions like moist earth. A treatise on walls, bins and grain elevators by Ketchum contains the best information available on this subject.

The parabolic type of bunker is easy to construct and brings no eccentric load of any magnitude to the columns carrying it.

A simple method of drawing a parabolic for any sag and span is shown by the illustration. The actual curve is slightly different from a parabola. The coal may be heaped from the edges towards the centre of the span at an angle depending upon the angle of repose of coal which is from 35° to 40°.

If D = the depth of the curve
S = the span
C = the capacity per foot of length
X = zero at the lowest point of the curve.

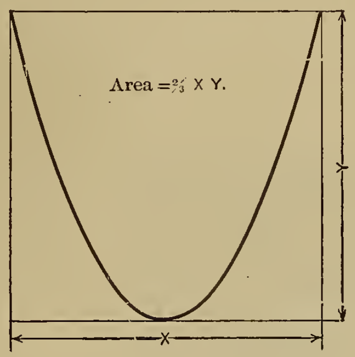
The correct equation becomes

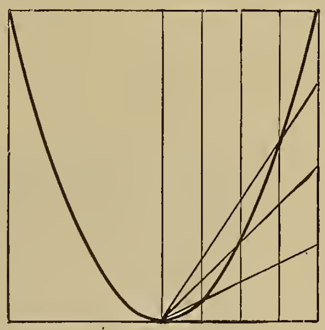
$$Y = \frac{2D}{S^2}\left(3X^2 - \frac{2X^3}{S}\right)$$

The capacity when filled level full is per foot of length C = .625 DS.

The supporting forces, the thrust brought to the compression members placed between the columns at the top and the tension in the upper ends of the plate, may be found graphically. The total horizontal tension in the plate at the bottom is the same as the total compression carried to the compression members at the top.

A parabolic pocket known as the Brown is constructed of steel straps, bent to the correct shape, riveted at either end to channel bars attached to the columns. These straps carry the load and are spaced from 3 feet to 4 feet 10 inches according to the weight to be carried. On these straps





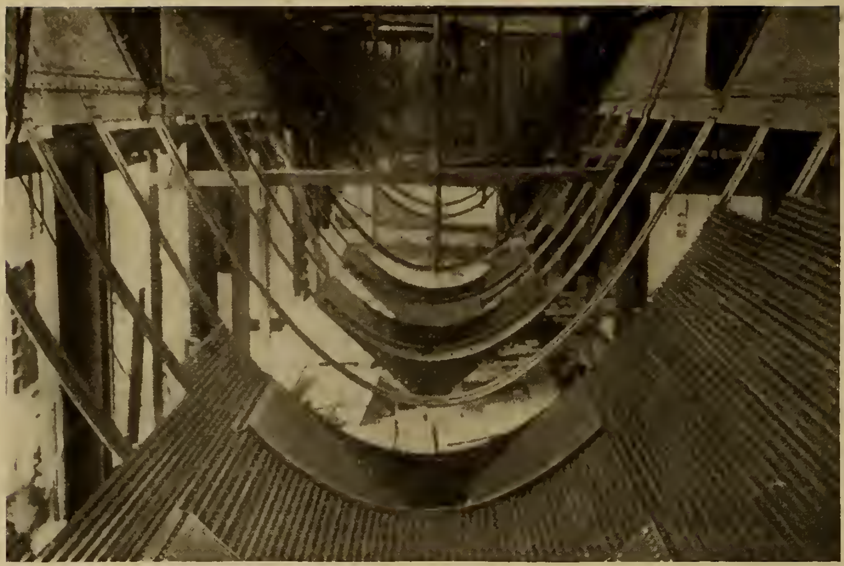
a special crimped steel sheet known as "ferro-inclave" is laid as a reinforcing material and a thickness of concrete from 2″ to 4″ plastered over the inside and a similar but thinner coating on the outside.

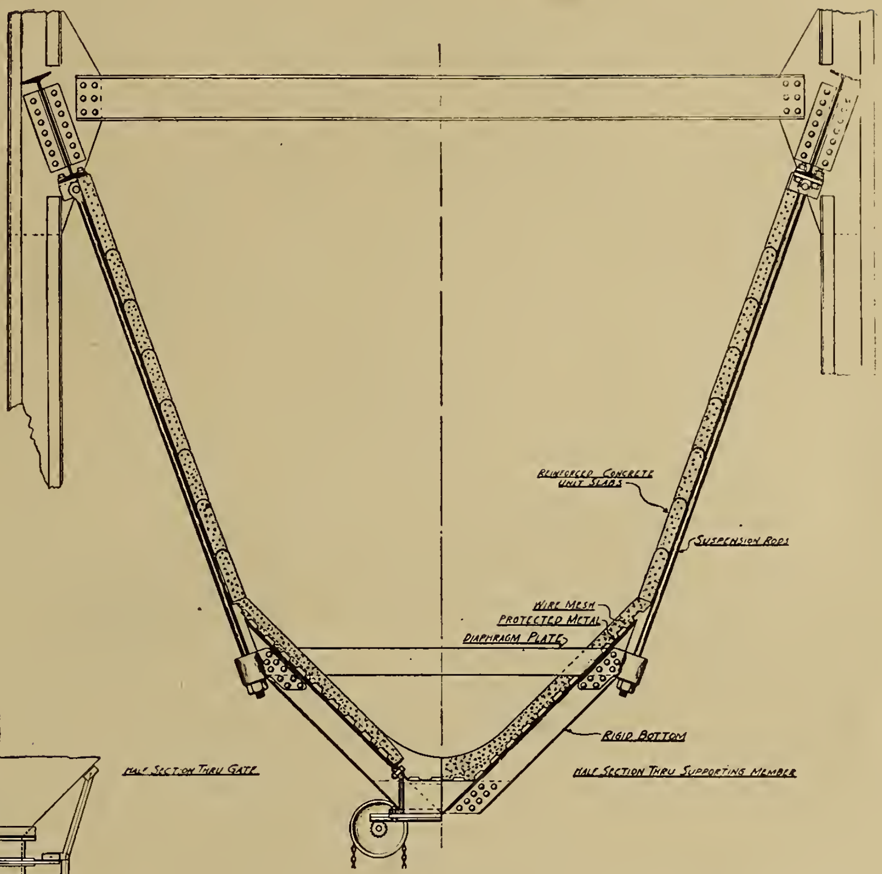
A section of "ferro-inclave" drawn full size is shown.

Where the coal valves are attached, a piece of steel plate is fastened to the straps as shown by the illustration.

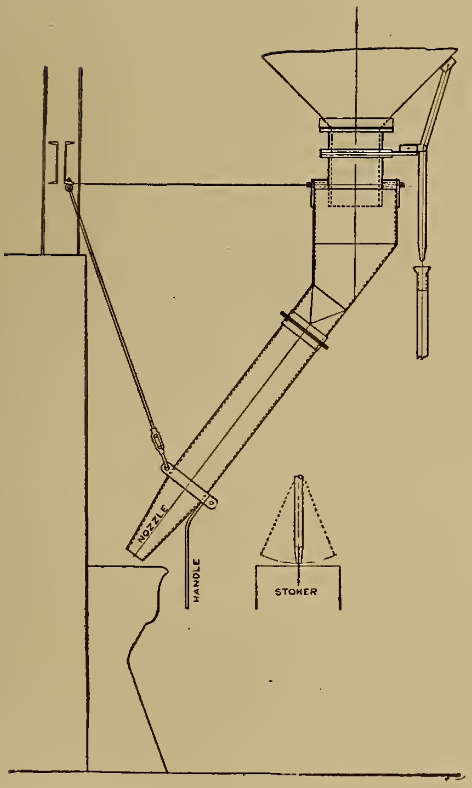
The "Baker" suspension type has a rigid bottom carried by suspension rods spaced longitudinally at such distances as the load warrants. Between the suspension rods unit reinforced concrete slabs having rounded ends form the sides of the bin. The bottom may be constructed as shown or made up of unit slabs like the side.

This method of constructing the sides allows of a bending of the rods, due to the loading of the pocket, without cracking the lining.





Unit Concrete Slab Bin.
"Baker" Suspension Type.

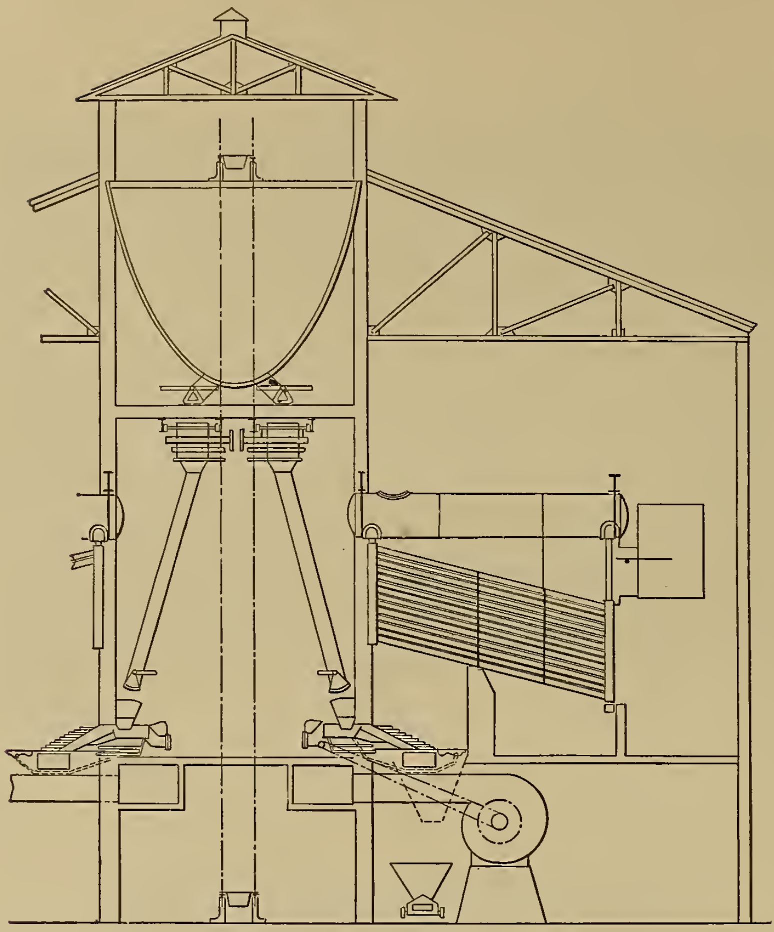


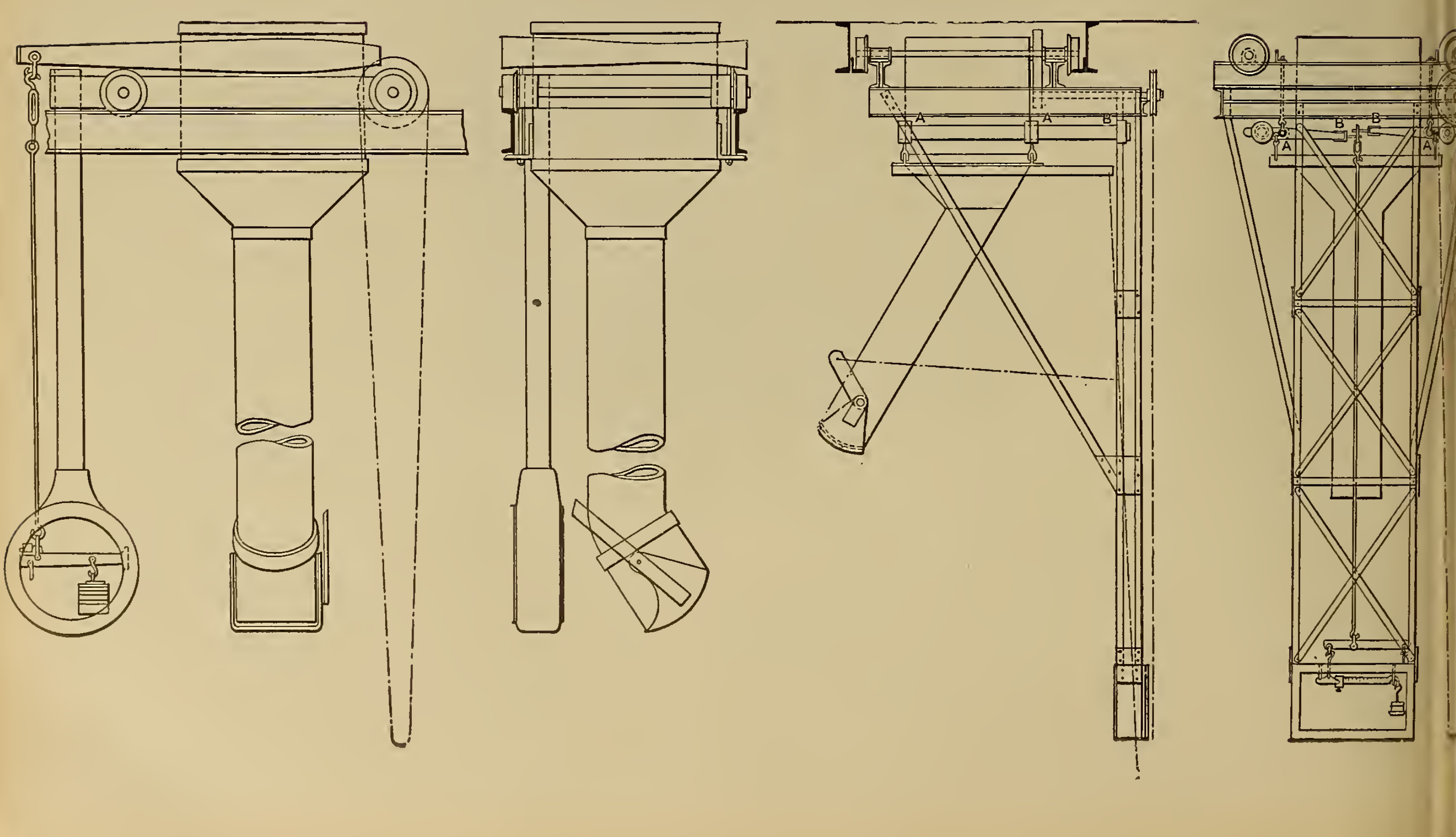
Coal may be taken from the coal pocket overhead into a weighing hopper and from this discharged to the stoker through a spout in front of each boiler. The end of the spout is frequently spread out fan like and known as a spreader. The nozzle type is preferable however.

The cut shows a spout with nozzle and with a swivel or universal joint at the top. The fireman by means of the handle directs the coal to any part of the stoker reservoir and fills same evenly.

Movable weighing hoppers of capacity up to one ton may be installed and operated from the floor in plants of moderate size (see illustration).

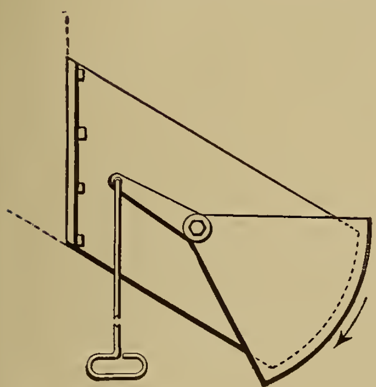
In large plants a motor driven crane carries a weighing hopper of larger size which travels under the coal pocket over the firing aisle and automatically records the weight of coal fed to each stoker.

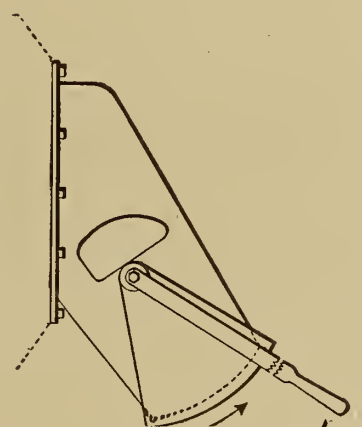


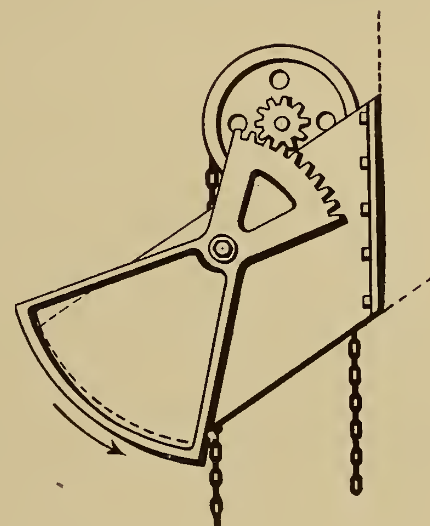


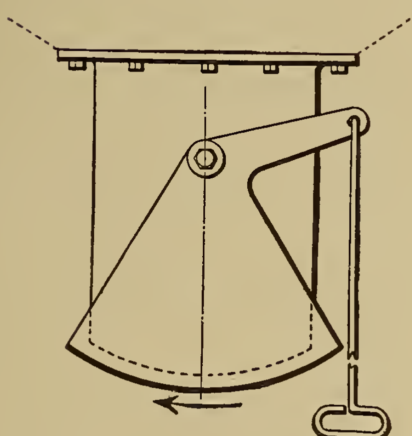
Cuts of two different weighing hoppers and a number of coal valves taken from Steam Boilers are given.

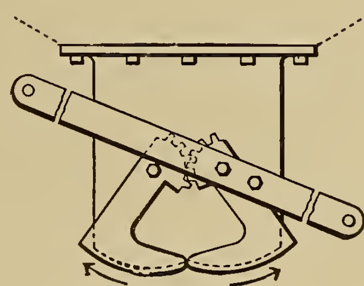
Volume of Ton of Coal	*Cu. Ft.*
Soft coal	41 to 43
Buckwheat or Pea	37
Nut	34
Furnace Size	36
Coke	76
Ash dry not packed	48 to 50











FOUNDATIONS

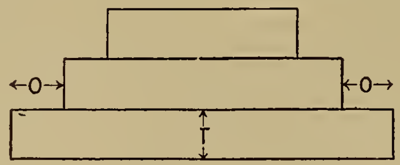
CONCRETE FLOORS, WALLS, ETC.

The type of foundation used will depend upon the character of the soil and upon the load to be brought to the soil.

Baker in his Masonry Construction gives the following safe bearing loads of soils. These values have been generally accepted.

	Tons per sq. ft. Min.	Max.
Clay in thick beds always dry	6	8
Clay in thick beds moderately dry	4	6
Clay soft	1	2
Gravel and coarse sand well cemented	8	10
Sand dry, compact, well cemented	4	6
Sand clean dry	2	4
Quicksand, Alluvial soils	.5	1

If the footing is spread sufficiently so that the load is carried by the soil it is customary to decrease the cross section of the footing as the depth decreases.



With a 1-2-4 concrete the allowable offset O is for a pressure on the soil of .5 ton per sq. ft $1.1t$, for a load of 1 ton $.8t$ and for a load of 2 tons $.5t$ where t is the thickness of the lower section of the footing.

In many cases, especially where the load coming to the footing is not the same per foot, as for example in the setting of a water tube boiler, it is customary to reinforce the footing with steel rods or with steel beams buried in the concrete.

If the land on which the structure is to be built, is made land, it will probably be necessary to put in piles to support the footing.

The piles may be either wooden or concrete. The wooden piles cost for oak 20 to 30 feet long 6″ top 12″ butt 17 cents per foot of length; oak 40 to 60 feet long, 21 to 25 cents per foot of length; spruce, 20 to 30 feet 15 cents per foot of length.

The cost of driving a pile and cutting off is about 9 cents a foot.

Concrete piles cost about $20 for a 40 foot length as against $9.50 for wooden piles; the bearing power of a concrete pile is however 2.5 times that of a wooden pile.

Wooden piles should not be driven closer than 30″ on centers.

The safe bearing load of a wooden pile may be figured with more or less uncertainty by what is known as the Wellington or the Engineering News formula:

P = safe load in lbs. (factor of six used)
M = weight of drop hammer in lbs.
h = fall of hammer in ft.
s = penetration or sinking in inches at last blow. This to be measured when there is no appreciable rebound of the hammer and the head of the pile is not broomed.

If there is a rebound the drop of hammer should be reduced.

$$P = \frac{2M\,h}{s+1}$$

Illustration

Hammer = 3000 lbs.
Drop in ft. = 10
Penetration = 3″

P = 15,000 lbs.

BRICKS

A mason and laborer will lay 1000 to 1500 bricks per day in a wall averaging 10″ to 12″ thick. The cost of labor per 1000 bricks laid, including mason and helper and cost of erecting stagings is from $8.00 to $8.50.

Bricks cost from $7.50 to $10.00 per 1000 and a thousand bricks will lay about 2 cubic yards of masonry.

It takes about 20 bricks 8¼″ x 4″ x 2¼″ per cubic foot; the masonry weighing 125 lbs. per cu. ft.

In a power house the floors are usually of reinforced concrete on steel beams. The boiler room floor is generally figured for 250 lbs. live load and the engine or turbine room for 400 lbs. live load.

The dead load of various types of floors may be estimated from the following approximate data: the weights are given per sq. ft. of surface.

Wooden wearing surface	4 lbs. per inch thick
Granolithic finish	12 lbs. per inch thick
Cinder filling	5 lbs. per inch thick
Stone concrete	12½ lbs. per inch thick
Cinder concrete	9 lbs. per inch thick
Plaster, 2 coats	5 lbs. per inch thick

The dead load of any roof may be estimated from the following:

5 ply felt and gravel roofing	6 lbs.
3 ply ready roofing	1 lb.
Slate 3/16 thick	7¼ lbs.
Clay tile	12 lbs.
Tin roofing	1 lb.
Copper roofing	2 lbs.
Corrogated iron	3 lbs.
Dry cinders	4 lbs.

The minimum live loads, for roofs pitching less than 20° vary from 30 to 50 lbs. per sq. ft. according to different City Bldg. Laws.

For a pitch greater than 20°, 25 to 30 lbs. should be used.

For light floor loads a 1-3-6 concrete might be used. This mixture might also be used in walls carrying but small loads. For heavy loads or for columns a 1-2-4 or richer mixture would be used.

REINFORCED CONCRETE FLOORS

Various types of reinforcing rods, woven wire fabric, welded wire fabric and expanded metal are used as reinforcing material in concrete floors. The woven fabrics and the expanded metal are made in certain definite sections and from tests which have been made on slabs of different thickness, the makers of the various reinforcing fabrics have constructed tables some of which have been given in these pages.

While tables might have been given for the strength of slabs reinforced by rods of one type or another, it was felt that one had better make his own calculations for such cases.

The formulae generally given for figuring reinforced concrete beams and slabs are derived on the assumption that (1) the tensile resistance of the concrete may be neglected and (2) that the stress diagram for the concrete is a straight line up to the safe compressive strength of the concrete.

The formulae and notation given below are practically as given in Turneaure and Maurer's Principles of Reinforced Concrete Construction. See also Baker's Treatise on Masonry Construction, Report of Joint Committees of Engineering Societies and Taylor & Thompson's Reinforced Concrete.

f_s = fibre stress in steel per sq. inch taken as 16 to 18,000 lbs.
f_c = fibre stress in concrete, the maximum compression per square inch at outer face; for 1-2-4 stone concrete from 600 to 700 lbs.; for 1-2-4 cinder concrete from 300 to 400 lbs.
E_s = elongation of steel per inch of length due to stress f_s per sq. inch.
E_c = shortening per inch of length of the concrete due to the stress f_c per sq. inch.
E_s = modulus of elasticity of steel.
E_c = modulus of elasticity of concrete in compression.

$n = \frac{E_s}{E_c}$ generally taken as 15 for 1-2-4 stone concrete and as 30 for 1-2-4 cinder concrete.

T = total tension in the steel at any section of the beam.
C = total compression in the concrete at any section.
M_s = resisting moment as determined by the steel; inch lbs.
M_c = resisting moment as determined by the concrete; inch lbs.
M = bending moment or resisting moment in general; inch lbs.
b = breadth of rectangular beam or slab in inches.
d = distance in inches from the compressive face of the concrete to the plane of the steel.
K = ratio of the depth of the neutral axis of a section below the top, to the distance d, generally taken as .375.
j = ratio of the arm of the resisting couple to the distance d.
A = area of cross section of the steel.

$P = \frac{A}{bd}$ = the steel ratio generally from .007 for a 1-2-4 cinder concrete to .0122 for a 1-2-4 stone concrete.

Since cross sections that were plane before bending remain plane after bending the unit deformations of the fibres vary as their distances from the neutral axis.

$$\frac{E_s}{E_c} = \frac{d - Kd}{Kd} \qquad E_s = \frac{f_s}{E_s}; \qquad E_c = \frac{f_c}{E_c}$$

$$\frac{E_s}{E_c} = \frac{f_s}{E_s} \times \frac{E_c}{f_c} = \frac{n_s}{f_c} = \frac{d - Kd}{Kd} = \frac{-K}{K}$$

as the total tension equals the total compression

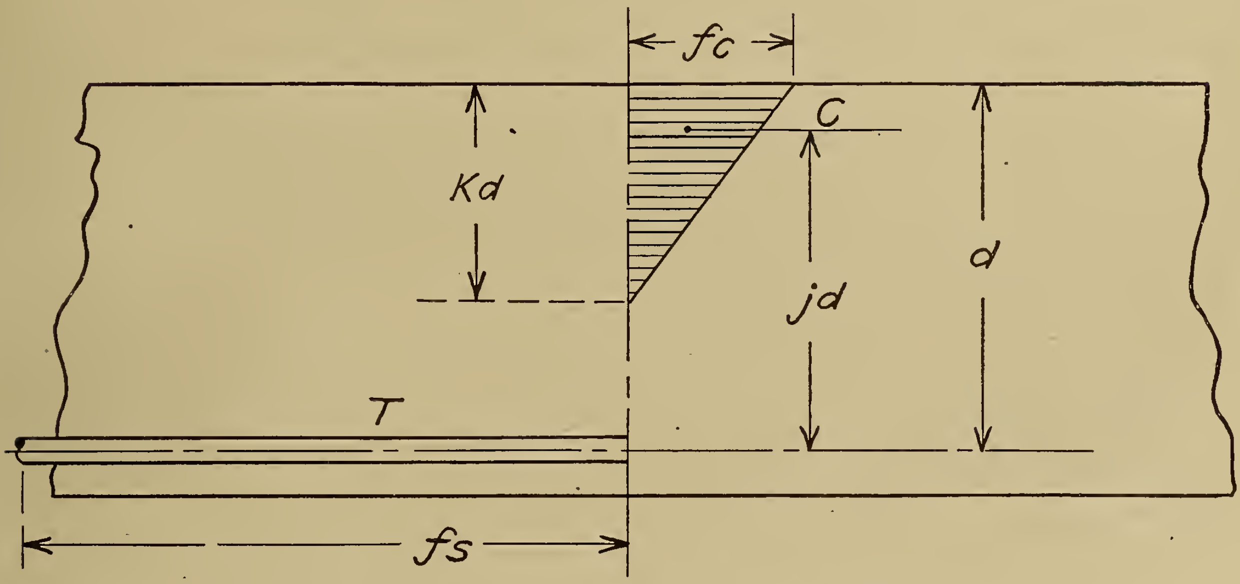
$$f_s A = \tfrac{1}{2} f_c\, b\, d\, K$$

$$f_s P\, b\, d = \tfrac{1}{2} f_c\, b\, d\, K; \qquad \frac{f_s}{f_c} P = \tfrac{1}{2} K$$

$$\text{but } \frac{f_s}{f_c} = n\left(\frac{1-K}{K}\right) \qquad \left(\frac{n - n\,K}{K}\right) P = \tfrac{1}{2} K$$

$$K^2 + 2\,Pn\,K + (Pn)^2 = 2\,Pn + (Pn)^2$$
$$K + Pn = \sqrt{2\,Pn + (Pn)^2}$$

from which K may be found as soon as the steel ratio is known and the ratio of $\frac{E_s}{E_c}$



$$j\,d = d - \tfrac{1}{3}\,Kd \qquad j = 1 - \tfrac{1}{3} K$$
$$\text{If } K = 0.375 \qquad j = 0.872 \text{ or about } \tfrac{7}{8}$$

A value of $j = .85$ is used by some designers on both cinder and stone concrete of 1-2-4 mixture

$$M_s = T\,j\,d = f_s A\,j\,d = f_s\,Pj\,b\,d^2$$
$$M_c = C\,j\,d = \tfrac{1}{2} f_c\, b\;K\,d\,j\,d = \tfrac{1}{2} f_c\;K\,j\,b\,d^2$$

The fibre stress in the steel for a given bending moment is equal to

$$f_s = \frac{M}{A\,j\,d} = \frac{M}{P\,j\,b\,d^2}$$

The fibre stress in the concrete $f_c = \frac{2\,M}{K\,j\,b\,d^2}$ equating values of M;

$$f_c = \frac{2\,f_s\,P}{K}; \qquad bd^2 = \frac{2\,M}{f_c\,Kj}; \qquad bd^2 = \frac{M}{f_s\,Pj}.$$

The bending moment for beams and for slabs continuous over the supports is $M = \frac{W\,l^2}{12}$, where W is the load per inch of length and l is the length in inches. If continuous over one support only $M = \frac{W\,l^2}{10}$ while if freely supported $M = \frac{W\,l^2}{8}$

If a rectangular slab be reinforced in two directions the bending moment would, for a square panel where one-half the load would be carried in each direction, be $M = \frac{W\,l^2}{20}$, where W is the total load per square inch.

For a rectangular panel the proportion of the load carried by the reinforcement placed the short way of the span is $r = \frac{l^4}{l^4 + b^4}$

The reinforcement for the short span is then figured taking as the bending moment $\frac{r\,W\,l^2}{10}$ and in a similar way the reinforcement for the long span by using a value of $M = \frac{(1 - r)\,W\,l^2}{10}$.

The distance from the center of the reinforcing bars to the bottom of the floor slab should be 1″; the distance between centers of adjacent bars at least 2½ diameters.

The distance from the side of a beam or slab to the center of the outer bar should be about 2 diameters of bar.

The bearing pressure per square inch where a slab rests on its supports is not to exceed 650 lbs. per sq. inch.

Concrete beams sometimes fail through diagonal tension; floor slabs seldom fail in this way. A beam or slab may be made safe against such failure by keeping the average shear on a concrete having a compressive strength at 28 days of 2000 lbs., under 40 lbs. per sq. in. in cases where the horizontal reinforcing steel is not bent so as to offer help in resisting diagonal tension: where the reinforcing material is bent so that it does offer help the average shear may be taken as 60 lbs. per sq. in.; where ample reinforcement for resisting diagonal tension is specially provided, the average shear in the concrete may be taken as 120 lbs. per sq. in.

As the horizontal and the vertical shear are of the same intensity, the unit shear may be

$$\text{expressed as} = \frac{\text{Vertical shear on Section}}{bjd}$$

j may be taken as .85 or .87.

In finding the area of reinforcing steel (A_s) necessary for width b if it be assumed that the concrete resist one third of the total shear (V) on this width, and the steel the remaining two-thirds, then for vertical stirrups spaced a distance (S) apart longitudinally

$$A_s = \frac{\frac{2}{3}\,V\,S}{f_s\,j\,d}$$

If the reinforcing material makes an angle of 45° then the area of the steel becomes .7 of this value.

If the safe bonding strength of steel rods be taken as 80 lbs. per sq. inch of rod surface, and as 40 lbs. per sq. inch of wire surface then calling (o) the entire surface per inch of length of rods in a section (b) the bond stress per unit of surface of the bars $= \frac{V}{jdo}$ which must be less than 80 for rods and less than 40 for wire.

Example:

A continuous slab 8′-4″ span is to carry a total load of 288 lbs. per sq. ft. — the slab to be of 1-2-4 stone concrete. Required depth of slab and area of reinforcement.

f_c = 650 lbs. sq. inch.
f_s = 16,000 lbs. sq. inch.
n = 15

$$\text{For strip 12'' wide } M = \frac{288 \times 100 \times 100}{12 \times 12} = 20{,}000$$

$$bd^2 = \frac{40{,}000}{650 \times .375 \times .872} = 188$$

$$P = \frac{20{,}000}{188 \times 16{,}000 \times .872} = .762\%$$

$$d^2 = \frac{188}{12} = 15.66 \qquad d = 3.96''$$

use 5″ slab.

Steel 4 × 12 × .00762 = .366 sq. ins. per ft. width

use ⅜″ rods spaced 3″ on centres.

$$\text{The unit shear} = \frac{1200}{12 \times .87 \times 4} = 29 \text{ lbs.}$$

$$\text{The bond stress} = \frac{1200}{.87 \times 4 \times (4 \times .375 \times \pi)} = 74 \text{ lbs.}$$

Some types of concrete floors are shown by illustrations taken from the Catalogue of the Clinton Wire Cloth Co., Clinton, Mass. The wire cloth consists of a wire mesh made up of a series of parallel longitudinal wires spaced certain distances apart and held at intervals by means of transverse wires arranged at right angles to the longitudinal ones and electrically welded to them at the points of intersection.

A regulation governing the use of any type of reinforcement for concrete floors in New York City requires that the system be subjected to a load test. The test is made upon a sample floor approximating as nearly as possible the conditions of actual construction, and the particular span, slab and reinforcement as tested are approved by the Bureau of Buildings for one-tenth of the load which the test specimen actually carries.

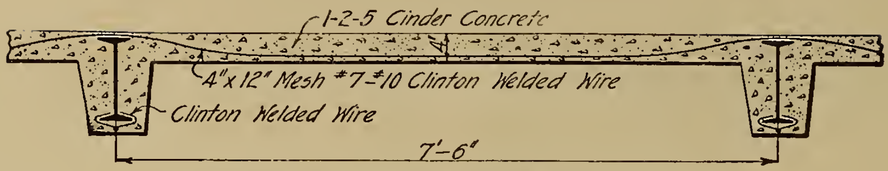
The following floor slabs have thus been tested in New York City and approved by the Bureau of Buildings for the various live loads as given:

The dias. of wire corresponding to W. & M. gages:

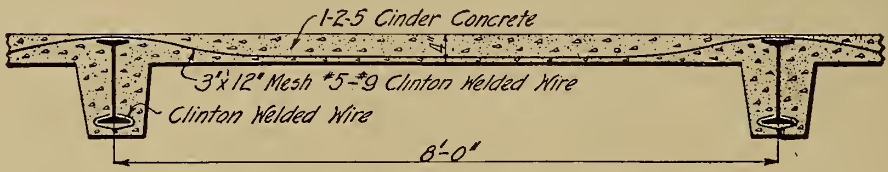
	dia.	area		dia.	area
No. 3	.331	.086	No. 7	.244	.047
No. 4	.307	.074	No. 8	.225	.040
No. 5	.283	.063	No. 9	.207	.034
No. 6	.263	.054	No. 10	.192	.029

In this type of reinforcement the wire is placed ¾″ above the bottom of the slab on all slabs from 3″ to through 4½″ in thickness; 1″ above on thicknesses of 5″, 6″ and 7″; and 1¼″ above on slabs 8″ thick.

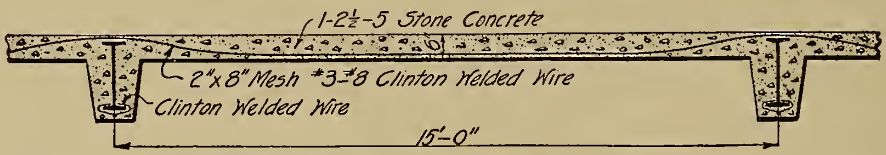
Another reinforcing material known as "steelcrete" made by the Eastern Expanded Metal Co. of Boston is shown by the illustration which appears on page 114.



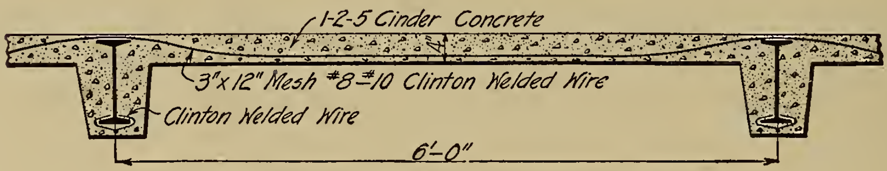
Approved Live Load 200 Pounds Per Square Foot



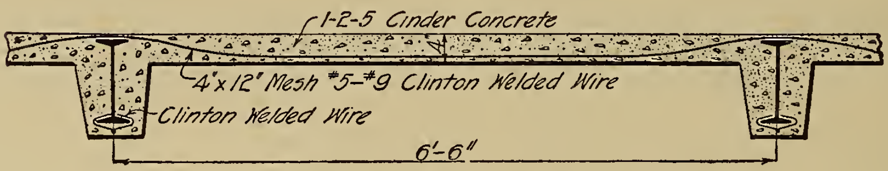
Approved Live Load 250 Pounds Per Square Foot



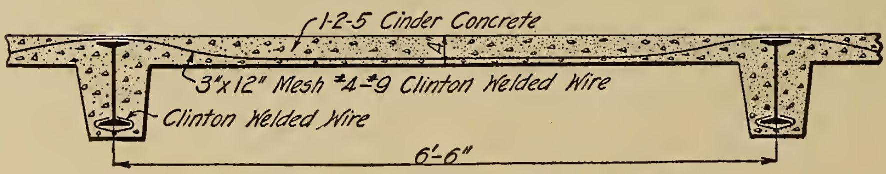
Approved Live Load 150 Pounds Per Square Foot



Approved Live Load 150 Pounds Per Square Foot



Approved Live Load 300 Pounds Per Square Foot

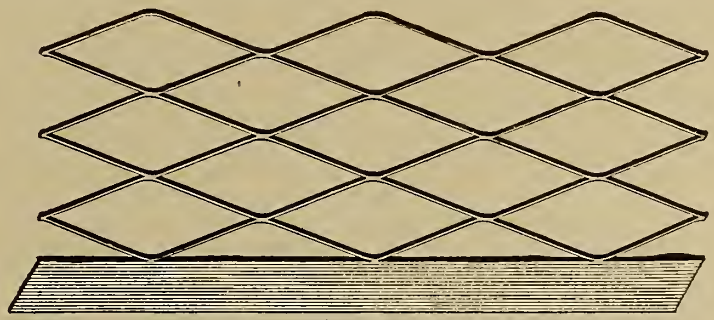


Approved Live Load 400 Pounds Per Square Foot

This cut also gives some idea of the method by which the mesh is manufactured.

"Steelcrete" can be obtained in lengths up to 144″ and in lengths less than 144″ varying by some multiple of 8″.

The size of the diamond, weight of reinforcement per sq. ft., etc., are given in the following table which has been taken from the maker's catalogue.



DECIMAL STANDARDS FOR "STEELCRETE" EXPANDED METAL

Designation of Mesh	Width of Diamond (Size of Mesh)	Length of Diamond (Size of Mesh)	Section in sq. in. per ft. of width	Wt. per square foot in lbs.	Number of Sheets in a bundle	Size of Standard Sheets	Number of sq. ft. in a bundle	Wt. per bundle in lbs.
3-13-075	3″	8″	.075	.27	10	6′0″ x 8′0″	480	129.6*
						6′0″ x 12′0″	720	194.4
3-13-10	3″	8″	.10	.37	7	6′9″ x 8′0″	378	139.9
						6′9″ x 12′0″	567	209.8
3-13-125	3″	8″	.125	.46	7	5′3″ x 8′0″	294	135.2
						5′3″ x 12′0″	441	202.9
3-9-15	3″	8″	.15	.55	5	7′0″ x 8′0″	280	154.0
						7′0″ x 12′0″	420	231.0
3-9-20	3″	8″	.20	.73	5	5′3″ x 8′0″	210	153.3
						5′3″ x 12′0″	315	230.0
3-9-25	3″	8″	.25	.92	5	4′0″ x 8′0″	160	147.2
						4′0″ x 12′0″	240	220.8
3-9-30	3″	8″	.30	1.10	2	7′0″ x 8′0″	112	123.2
						7′0″ x 12′0″	168	184.8
3-9-35	3″	8″	.35	1.28	2	6′0″ x 8′0″	96	122.9
						6′0″ x 12′0″	144	184.3
3-6-40	3″	8″	.40	1.46	2	7′0″ x 8′0″	112	163.5
						7′0″ x 12′0″	168	245.3
3-6-45	3″	8″	.45	1.65	2	6′3″ x 8′0″	100	165.0
						6′3″ x 12′0″	150	247.5
3-6-50	3″	8″	.50	1.83	2	5′9″ x 8′0″	92	168.4
						5′9″ x 12′0″	138	252.5
3-6-55	3″	8″	.55	2.01	2	5′3″ x 8′0″	84	168.8
						5′3″ x 12′0″	126	253.3
3-6-60	3″	8″	.60	2.19	2	4′9″ x 8′0″	76	166.4
						4′9″ x 12′0″	114	249.7
3-6-75	3″	8″	.75	2.74	2	3′9″ x 8′0″	60	164.4
						3′9″ x 12′0″	90	246.6
3-6-100	3″	8″	1.00	3.66	2	2′9″ x 8′0″	44	161.0
						2′9″ x 12′0″	66	241.6

"STEELCRETE" SPECIAL MESHES

¾-13-25	.95″	2″	.225	.80	5	6′0″ x 8′0″	240	192.0
1½-13-20	1.36″	3″	.181	.73	5	4′0″ x 8′0″	240	116.8
2-13-15	1.82″	4″	.15	.50	5	5′0″ x 8′0″	200	100.0

"Steelcrete" MESH SLAB TABLES

for use with

GRAVEL OR STONE CONCRETE.

Maximum Stress in Steel = 18,500 lbs. per sq. inch.
Maximum Stress in Concrete = 750 lbs. per sq. inch.

Maximum Bending Moment = $M = \frac{1}{12} w l^2$.
where
w = total load per sq. ft.
l = center to center span.

3-13-075 "Steelcrete" Expanded Metal. Area = 0.075 sq. in. per ft. of width.

Slab	Span									Unit Stresses lbs. per sq. in.	
	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	9'-0"	Concrete	Steel
3"	143	105	78	58	43	31	22				455	18,500
3½	178	131	98	73	55	40	29	19			405	"
4	214	158	119	89	67	50	36	25			370	"
4½	250	185	140	106	80	60	44	31	20		340	"
5	286	213	161	122	93	70	52	37	25		325	"
6	357	266	201	153	117	89	66	48	33		290	"
7	429	321	243	186	142	109	82	60	42	15	260	"
8	500	374	284	218	167	127	96	71	50	19	240	"
9	574	430	327	251	193	148	112	83	60	24	220	"
10	646	484	369	283	218	167	127	94	68	27	210	"
11	719	539	411	316	244	187	143	107	77	32	200	"
12"	792	594	453	348	269	207	158	118	85	36	190	"

3-13-10 "Steelcrete" Expanded Metal. Area = 0.100 sq. in. per ft. of width.

Slab	Span										Unit Stresses lbs. per sq. in.	
	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	9'-0"	10'-0"	Concrete	Steel
3"	201	151	115	89	69	53	41	31	23			540	18,500
3½	249	188	144	111	86	67	52	39	29			480	"
4	298	225	173	134	105	82	64	49	37	19		435	"
4½	348	263	203	158	124	97	76	59	45	24		400	"
5	398	302	232	181	142	112	88	69	53	29		375	"
6	496	376	290	227	179	141	112	87	68	38		330	"
7	597	453	351	275	217	172	136	107	84	48	22	305	"
8	697	530	410	321	254	202	160	127	99	57	27	280	"
9	798	607	470	369	292	232	185	147	115	68	34	260	"
10	896	682	529	415	329	262	209	165	130	77	38	245	"
11	998	761	590	464	368	293	234	186	147	87	45	230	"
12"	1098	836	650	510	405	323	258	205	162	97	50	220	"

3-13-125 "Steelcrete" Expanded Metal. Area = 0.125 sq. in. per ft. of width.

Slab	Span												Unit Stresses lbs. per sq. in.	
	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	9'-0"	10'-0"	11'-0"	12'-0"	Concrete	Steel
3"	258	196	152	119	94	75	59	47	37	21				610	18,500
3½	319	243	188	148	117	94	75	59	47	28				545	"
4	382	291	226	178	142	113	91	73	58	35	19			490	"
4½	445	340	265	209	167	134	108	86	69	43	24			455	"
5	508	388	303	240	191	154	124	100	80	51	29			425	"
6	635	486	379	300	240	194	157	127	102	65	39	19		380	"
7	762	584	457	362	290	234	190	155	125	81	49	25		345	"
8	889	681	533	423	340	275	223	181	147	96	58	31		320	"
9	1018	782	612	486	390	316	257	210	171	111	69	37		300	"
10	1145	878	688	547	440	356	290	236	193	126	78	43	16	275	"
11	1275	979	767	610	491	398	324	265	216	142	89	50	20	265	"
12"	1403	1076	844	672	541	438	357	292	238	157	99	55	23	250	"

Slab	3-9-15 "Steelcrete" Expanded Metal. Area = 0.150 sq. in. per ft. of width. Span														Unit Stresses. lbs. per sq. in.	
	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	9'-0"	10'-0"	11'-0"	12'-0"	13'-0"	Concrete	Steel.
3"	314	240	187	148	119	96	77	63	51	32	19				675	18,500
3½	389	298	233	185	148	120	97	79	64	42	25				605	"
4	464	357	279	222	179	145	118	96	79	52	32				550	"
4½	541	416	326	260	209	170	139	114	93	62	40	23			505	"
5	618	476	374	298	241	196	160	132	108	72	47	28			470	"
6	771	594	467	373	301	245	201	166	137	92	60	37	19		420	"
7	927	715	562	449	364	297	244	202	167	113	75	47	26		380	"
8	1081	834	656	525	425	348	286	236	195	133	89	56	31		350	"
9	1237	954	752	602	488	399	329	272	225	155	104	66	38		330	"
10	1394	1075	847	678	550	450	371	307	255	175	118	76	44	19	305	"
11	1550	1197	943	756	613	503	414	343	285	197	133	86	51	23	290	"
12"	1705	1316	1037	832	675	553	456	378	314	217	147	95	56	26	275	"

Slab	3-9-20 "Steelcrete" Expanded Metal. Area = 0.200 sq. in. per ft. of width. Span.																Unit Stresses lbs. per sq. in.	
	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	9'-0"	10'-0"	11'-0"	12'-0"	13'-0"	14'-0"	15'-0"	Concrete	Steel.
3"	397	306	241	193	156	128	105	87	72	49	33	20					750	17,400
3½	525	406	320	257	209	171	142	118	98	68	47	31	19				710	18,500
4	628	486	384	309	251	207	171	143	120	84	58	40	25				645	"
4½	731	566	448	360	294	242	201	168	141	100	70	48	32	19			595	"
5	836	647	512	413	337	278	231	193	162	115	82	57	38	23			555	"
6	1041	808	640	516	421	348	290	243	204	146	104	73	49	31			490	"
7	1251	970	770	621	508	420	350	294	248	177	127	90	62	40	22		445	"
8	1461	1133	899	726	594	491	410	344	290	208	150	106	73	48	27		410	"
9	1671	1297	1030	832	681	564	479	396	334	241	173	124	86	57	34		380	"
10	1880	1460	1159	936	767	635	530	446	377	271	196	140	98	65	39	18	360	"
11	2093	1624	1289	1042	854	707	591	497	421	304	220	158	111	74	45	22	340	"
12"	2302	1788	1420	1147	940	779	651	548	463	335	242	174	123	82	50	24	320	"

Slab	3-9-25 "Steelcrete" Expanded Metal. Area = 0.250 sq. in. per ft. of width. Span																			Unit Stresses lbs. per sq. in	
	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	9'-0"	10'-0"	11'-0"	12'-0"	13'-0"	14'-0"	15'-0"	16'-0"	17'-0"	18'-0"	Concrete	Steel.
3"	428	330	261	209	170	139	115	95	79	55	37	24								750	15,100
3½	608	471	373	301	246	203	169	141	119	85	60	42	28							"	17,200
4	787	612	486	393	322	267	223	188	159	115	84	61	43	29	18					730	18,500
4½	916	712	566	458	376	312	262	221	187	136	100	73	52	36	23					675	"
5	1048	816	649	526	431	358	301	254	216	157	116	85	61	43	29					630	"
6	1309	1019	811	657	540	449	377	319	271	198	146	108	79	56	38	23				560	"
7	1571	1223	974	790	650	541	455	385	328	241	178	132	97	70	48	31	17			505	"
8	1834	1428	1137	923	760	632	531	450	384	282	209	156	115	83	58	38	21			460	"
9	2099	1637	1304	1058	872	726	610	518	441	325	242	181	134	98	69	45	26			430	"
10	2364	1840	1467	1191	980	817	687	583	497	366	273	204	151	111	78	52	30			405	"
11	2631	2051	1633	1325	1092	910	766	649	555	409	305	229	170	125	89	60	36			385	"
12"	2898	2258	1800	1461	1205	1004	845	717	612	452	338	253	189	138	99	67	40	19		360	"

Slab	3-9-30 "Steelcrete" Expanded Metal. Area = 0.300 sq. in. per ft. of width. Span.																			Unit Stresses lbs. per sq. in.	
	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	9'-0"	10'-0"	11'-0"	12'-0"	13'-0"	14'-0"	15'-0"	16'-0"	17'-0"	18'-0"	Concrete	Steel.
3"	456	353	279	224	182	150	124	103	86	61	42	28								750	13,500
3½	645	500	397	320	262	217	181	152	128	92	66	47	33							"	15,300
4	866	674	536	435	357	297	249	211	179	131	97	71	52	37	25					"	17,000
4½	1102	858	685	556	458	382	322	273	233	173	129	97	73	54	39	26				"	18,500
5	1259	982	784	637	526	438	369	314	269	199	149	113	85	63	46	32	21			700	"
6	1574	1227	980	797	658	549	463	394	337	251	189	143	108	81	60	42	28			620	"
7	1891	1475	1179	959	792	662	559	475	408	304	229	174	133	100	74	54	37	23		560	"
8	2205	1721	1375	1119	924	773	653	556	476	355	269	205	156	118	88	64	44	28		515	"
9	2526	1970	1576	1283	1060	886	749	638	547	409	310	237	181	138	103	76	53	34		475	"
10	2842	2217	1774	1444	1193	998	844	719	617	461	350	267	205	156	117	86	60	39	22	445	"
11	3163	2472	1974	1608	1329	1113	941	802	688	515	391	299	230	175	132	98	69	46	26	420	"
12"	3488	2722	2179	1773	1466	1226	1037	884	759	568	432	331	254	194	147	109	77	51	30	400.	"

3-9-35 "Steelcrete" Expanded Metal. Area = 0.350 sq. in. per ft. of width																				Unit Stresses. lbs. per sq. in.	
Slab.	Span.																				
	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	9'-0"	10'-0"	11'-0"	12'-0"	13'-0"	14'-0"	15'-0"	16'-0"	17'-0"	18'-0"	Concrete	Steel.
3"	480	372	294	236	193	159	132	110	92	65	46	31	20							750	12,200
3½	682	529	420	340	278	231	193	162	137	99	72	52	37	25						"	13,900
4	908	707	563	457	376	313	263	222	190	139	103	77	56	41	28					"	15,400
4½	1166	910	726	590	488	407	343	292	250	185	140	106	80	60	44	31	20			"	16,900
5	1446	1129	903	736	608	509	430	367	315	236	179	137	106	81	61	45	32	22		"	18,200
6	1835	1434	1148	936	775	649	549	469	403	302	231	178	137	106	81	61	44	31	19	675	18,500
7	2203	1723	1379	1125	931	781	661	565	486	366	280	216	168	130	100	76	56	40	26	610	"
8	2576	2013	1613	1315	1089	913	774	661	569	429	328	254	197	153	118	90	67	48	32	560	"
9	2948	2306	1846	1506	1248	1047	887	758	653	492	378	292	228	178	138	106	79	57	39	520	"
10	3320	2596	2079	1697	1406	1179	1000	855	736	556	427	330	258	201	156	120	90	66	45	490	"
11	3694	2891	2314	1890	1566	1313	1114	953	821	620	476	369	289	226	176	136	103	75	52	460	"
12"	4070	3185	2550	2082	1726	1449	1229	1050	906	684	526	408	319	250	195	150	114	84	58	440	"

3-6-40 "Steelcrete" Expanded Metal. Area = 0.400 sq. in. per ft. of width.																				Unit Stresses lbs. per sq. in.	
Slab.	Span																				
	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	7'-6	8'-0"	9'-0"	10'-0"	11'-0"	12'-0"	13'-0"	14'-0"	15'-0"	16'-0"	17'-0"	18'-6	Concrete	Steel.
3"	503	389	308	248	203	167	139	117	98	70	49	34	23							750	11,300
3½	713	554	441	356	292	243	203	171	145	106	77	56	40	28						"	12,800
4	954	743	592	481	396	330	278	236	201	148	111	83	62	45	32	21				"	14,200
4½	1219	952	760	619	511	427	361	307	263	196	148	113	86	65	48	35	24			"	15,500
5	1517	1185	948	773	640	536	454	387	333	250	191	147	113	88	67	50	37	25		"	16,800
6	2090	1636	1311	1070	888	745	632	541	467	353	271	211	166	130	102	79	60	45	32	730	18,500
7	2513	1968	1578	1289	1069	898	763	653	563	427	329	257	202	159	125	98	76	57	41	660	"
8	2938	2300	1844	1506	1250	1050	892	764	660	500	386	302	238	188	148	116	90	68	50	610	"
9	3368	2638	2116	1728	1434	1206	1024	878	758	576	444	348	275	217	172	135	105	81	60	565	"
10	3795	2970	2383	1946	1615	1359	1154	989	855	649	501	393	310	246	195	153	120	92	69	530	"
11	4218	3303	2652	2165	1798	1512	1285	1101	951	723	559	439	347	275	218	173	135	104	78	495	"
12"	4650	3640	2920	2388	1981	1666	1416	1214	1050	798	618	484	383	304	242	191	150	116	87	470	"

3'-6-45 "Steelcrete" Expanded Metal. Area = 0.450 sq. in. per ft. of width																				Unit Stresses lbs. per sq. in.	
Slab.	Span.																				
	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	9'-0"	10'-0"	11'-0"	12'-0"	13'-0"	14'-0"	15'-0"	16'-0"	17'-0"	18'-0"	Concrete	Steel.
3"	521	404	320	258	211	174	145	122	102	73	52	37	25							750	10,400
3½	738	574	457	370	304	253	212	179	152	111	81	59	43	30	20					"	11,800
4	991	772	616	501	413	344	290	246	210	156	117	88	66	49	35	24				"	13,200
4½	1268	990	792	644	532	446	376	321	275	206	156	119	91	69	52	38	27			"	14,400
5	1574	1231	985	804	666	558	472	403	347	261	200	154	120	93	72	54	40	29	19	"	15,600
6	2255	1766	1417	1158	961	808	686	588	508	385	298	233	184	146	115	91	71	54	40	"	17,800
7	2823	2213	1776	1453	1207	1016	864	741	641	488	379	298	236	189	151	120	95	74	57	705	18,500
8	3305	2590	2080	1700	1413	1189	1011	868	751	572	444	350	278	222	178	142	113	88	68	650	"
9	3783	2963	2378	1948	1618	1362	1159	995	861	657	511	402	320	257	206	165	131	103	80	605	"
10	4255	3340	2680	2194	1823	1535	1306	1121	971	741	577	455	362	290	233	187	149	118	91	565	"
11	4743	3718	2983	2443	2031	1711	1456	1251	1083	827	643	508	405	325	261	210	168	133	104	530	"
12"	5225	4095	3290	2692	2240	1885	1605	1379	1194	911	710	560	447	359	289	232	186	148	115	505	"

3-6-50 "Steelcrete" Expanded Metal. Area = 0.500 sq. in. per ft. of width.																				Unit Stresses lbs. per sq. in.	
Slab	Span.																				
	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	9'-0"	10'-0"	11'-0"	12'-0"	13'-0"	14'-0"	15'-0"	16'-0"	17'-0"	18'-0"	Concrete	Steel.
4"	1026	800	638	519	428	358	302	256	219	163	122	92	70	52	38	27				750	12,300
4½	1320	1030	824	672	556	465	393	335	288	216	164	126	97	74	56	42	30			"	13,500
5	1628	1273	1019	832	689	578	490	419	360	272	208	161	126	98	76	58	44	32	21	"	14,600
6	2340	1833	1471	1203	999	840	714	612	529	402	311	244	193	154	122	97	76	59	44	"	16,700
7	3131	2453	1973	1614	1342	1131	963	828	717	548	427	338	270	217	176	142	114	91	72	"	18,500
8	3660	2870	2305	1888	1570	1323	1127	969	840	642	502	397	318	256	207	167	135	108	86	690	"
9	4193	3288	2643	2166	1801	1518	1294	1112	964	739	577	457	366	296	239	194	157	126	101	640	"
10	4725	3705	2977	2438	2029	1710	1458	1254	1087	833	651	516	413	334	271	220	178	143	114	600	"
11	5263	4128	3321	2721	2263	1908	1627	1399	1213	929	727	577	463	374	304	247	200	162	130	565	"
12"	5790	4545	3650	2991	2490	2100	1790	1540	1335	1024	801	635	510	412	335	273	221	179	143	540	"

3-6-55 "Steelcrete" Expanded Metal. Area = 0.550 sq. in. per ft. of width.

Slab	Span 4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	9'-0"	10'-0"	11'-0"	12'-0"	13'-0"	14'-0"	15'-0"	16'-0"	17'-0"	18'-0"	Unit Stresses lbs. per sq. in. Concrete	Steel.
4"	918	715	570	462	380	317	266	225	192	141	105	78	58	42	29	19				750	11,000
4½	1199	936	748	608	502	419	354	301	258	192	145	110	83	63	46	33	22			"	12,100
5	1510	1180	945	770	637	534	452	385	331	249	190	146	113	87	66	50	36	25		"	13,200
6	2215	1735	1391	1136	943	793	673	577	498	378	292	228	180	142	112	88	68	52	38	"	15,200
7	3028	2373	1906	1560	1297	1092	930	799	691	528	411	325	259	208	167	134	108	85	67	"	17,100
8	3870	3035	2440	1999	1663	1402	1196	1028	892	684	535	424	341	276	224	182	148	120	96	740	18,500
9	4448	3493	2809	2303	1918	1617	1378	1186	1029	790	618	492	395	320	261	213	173	141	113	690	"
10	5040	3955	3180	2607	2173	1831	1560	1344	1166	895	701	558	449	364	297	242	198	161	130	640	"
11	5628	4418	3553	2913	2424	2046	1746	1503	1304	1001	785	625	504	409	334	273	223	182	148	605	"
12"	6215	4880	3925	3220	2680	2260	1930	1660	1441	1108	869	692	558	453	370	303	248	202	165	575	"

3-6-60 "Steelcrete" Expanded Metal. Area = 0.600 sq. in. per ft. of width

Slab	Span 4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	9'-0"	10'-0"	11'-0"	12'-0"	13'-0"	14'-0"	15'-0"	16'-0"	17'-0"	18'-0"	Unit Stresses lbs. per sq. in. Concrete	Steel.
4"	941	734	584	474	391	325	274	232	198	146	109	81	60	44	31	21				750	10,400
4½	1235	964	770	627	518	433	366	311	267	199	151	115	88	66	49	36	25			"	11,500
5	1553	1214	972	793	656	550	466	397	342	257	197	152	117	91	70	53	39	27	18	"	12,500
6	2278	1785	1431	1170	971	817	693	595	513	390	302	236	187	148	117	92	72	55	41	"	14,400
7	3111	2441	1961	1604	1334	1124	957	823	713	545	425	336	268	216	174	140	113	90	71	"	16,100
8	4045	3175	2552	2091	1742	1470	1253	1079	936	719	563	448	361	292	238	195	159	129	105	"	17,800
9	4848	3803	3058	2508	2088	1765	1507	1298	1127	868	681	543	439	357	292	240	198	162	133	720	18,500
10	5480	4305	3465	2840	2365	1997	1705	1470	1277	983	772	616	498	406	333	274	225	185	152	675	"
11	6128	4813	3873	3175	2646	2234	1908	1645	1428	1100	865	691	559	456	374	308	255	210	172	635	"
12"	6770	5320	4280	3510	2925	2470	2110	1820	1580	1217	957	765	619	506	415	342	283	233	192	600	"

3-6-75 "Steelcrete" Expanded Metal. Area = 0.750 sq. in. per ft. of width.

Slab	Span 4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	9'-0"	10'-0"	11'-0"	12'-0"	13'-0"	14'-0"	15'-0"	16'-0"	17'-0"	18'-0"	Unit Stresses lbs. per sq. in. Concrete	Steel.
5"	1486	1162	930	757	626	524	444	378	325	244	186	143	110	85	64	48	35	24		750	10,400
6	2238	1754	1406	1149	953	801	681	583	503	382	295	231	182	144	114	90	70	53	39	"	12,100
7	3118	2443	1963	1608	1337	1126	959	824	714	546	425	337	269	216	175	141	113	90	71	"	13,700
8	4090	3208	2580	2113	1760	1485	1266	1090	946	727	570	454	365	296	242	198	162	132	106	"	15,100
9	5173	4068	3273	2686	2238	1889	1614	1391	1210	932	734	587	476	389	320	264	218	181	149	"	16,500
10	6350	4995	4020	3303	2754	2327	1990	1718	1495	1154	911	731	595	488	403	336	280	234	195	"	17,800
11	7403	5823	4688	3853	3215	2718	2325	2008	1748	1353	1069	860	701	577	479	399	334	280	235	730	18,500
12	8210	6460	5205	4275	3568	3018	2580	2229	1940	1502	1188	955	779	642	533	444	372	313	263	690	"
13	9013	7088	5713	4693	3918	3313	2836	2448	2132	1652	1307	1051	857	706	588	490	412	346	291	655	"
14	9825	7725	6225	5115	4270	3613	3088	2668	2325	1799	1425	1146	935	771	641	536	450	379	319	630	"
15	10633	8363	6733	5533	4623	3908	3343	2888	2515	1951	1543	1243	1014	836	696	582	489	411	347	600	"
16"	11440	9000	7250	5960	4975	4210	3600	3110	2710	2100	1662	1341	1093	902	750	628	528	444	375	580	"

3-6-100 "Steelcrete" Expanded Metal. Area = 1.000 sq. in. per ft. of width.

Slab	Span 4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	9'-0"	10'-0"	11'-0"	12'-0"	13'-0"	14'-0"	15'-0"	16'-0"	17'-0"	18'-0"	Unit Stresses lbs. per sq. in. Concrete	Steel.
5"	1613	1262	1010	824	683	573	486	415	357	269	206	160	124	97	75	57	43	31	21	750	8,600
6	2447	1918	1540	1259	1046	881	749	643	556	423	329	259	205	164	131	104	83	65	50	"	10,100
7	3413	2681	2153	1764	1468	1239	1056	909	789	605	473	376	302	244	199	162	132	107	86	"	11,400
8	4485	3520	2835	2325	1938	1636	1398	1204	1046	806	634	506	409	334	274	226	187	154	126	"	12,600
9	5678	4463	3593	2950	2463	2080	1778	1534	1336	1032	815	654	531	436	361	300	250	209	174	"	13,800
10	6970	5480	4415	3627	3030	2564	2193	1893	1649	1276	1010	813	663	547	454	379	319	268	225	"	14,800
11	8363	6583	5303	4363	3643	3083	2642	2282	1990	1543	1223	987	808	668	557	467	394	334	283	"	15,900
12	9900	7795	6285	5170	4320	3660	3132	2710	2363	1835	1459	1179	966	802	671	565	478	407	346	"	16,900
13	11478	9038	7288	5993	5008	4248	3638	3148	2748	2138	1700	1377	1131	940	788	666	566	482	413	"	17,900
14	12955	10195	8235	6795	5665	4800	4115	3565	3110	2420	1925	1561	1284	1069	897	759	646	552	474	740	18,500
15	14023	11043	8913	7333	6133	5193	4453	3858	3368	2622	2087	1693	1392	1159	973	824	702	600	515	710	"
16"	15110	11900	9600	7900	6605	5600	4800	4155	3630	2825	2250	1825	1501	1250	1050	889	757	648	556	680.	"

"Steelcrete" MESH SLAB TABLES

for use with

CINDER CONCRETE.

Maximum Stress in Steel = 16,000 lbs. per sq. inch.
Maximum Stress in Concrete = 300 lbs. per sq. inch.

Maximum Bending Moment = $M = \frac{1}{12} w l^2$.
where
w = total load per sq. ft.
l = center to center span.

3-13-075 "Steelcrete" Expanded Metal: Area = 0.075 sq. in per ft. of width.

Slab	Span										Unit Stresses lbs. per sq. in.	
	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	9'-0"	Concrete	Steel.
3"	121	89	67	50	38	28	20				265	16,000
3½	151	112	84	64	48	36	26	19			235	"
4	182	136	103	79	60	45	34	25			215	"
4½	213	159	121	92	71	54	41	30	21		200	"
5	244	182	138	106	82	62	47	35	25		185	"
6	305	229	174	134	103	80	61	45	33	14	165	"
7	368	277	212	163	126	98	75	57	42	19	150	"
8	430	323	247	191	148	115	89	67	50	23	135	"
9	494	372	285	220	172	133	103	79	59	28	125	"
10	555	418	320	248	193	150	116	89	67	33	120	"
11	619	467	358	278	217	169	131	101	76	38	110	"
12"	682	515	395	306	239	187	145	112	84	42	105	"

3-13-10 "Steelcrete" Expanded Metal. Area = 0.100 sq. in. per ft of width

Slab	Span												Unit Stresses lbs. per sq. in.	
	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	9'-0"	10'-0"	11'-0"	Concrete	Steel.
3"	157	118	90	69	54	41	32	24					300	15,100
3½	209	158	122	95	74	58	45	35	27				280	16,000
4	252	191	148	115	91	72	57	45	35	19			255	"
4½	294	223	173	135	107	85	67	53	41	24			235	"
5	336	255	198	155	123	97	77	61	48	28			220	"
6	420	320	248	195	155	123	98	78	62	37			195	"
7	507	387	301	237	188	150	120	96	77	46	25		175	"
8	593	452	352	277	221	177	142	113	90	55	30		160	"
9	678	518	403	318	254	204	164	131	105	65	36		150	"
10	765	584	455	359	287	230	185	149	119	74	42	18	140	"
11	853	651	508	401	320	258	208	167	134	84	48	22	130	"
12"	938	717	559	442	353	284	229	185	148	93	54	24	125	"

3-13-125 "Steelcrete" Expanded Metal. Area = 0.125 sq. in. per ft of width

Slab	Span													Unit Stresses lbs. per sq. in.	
	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	9'-0"	10'-0"	11'-0"	12'-0"	Concrete	Steel.
3"	170	129	99	76	60	46	36	28	21					300	13,100
3½	245	187	145	114	90	72	57	46	36	21				"	14,900
4	320	245	191	152	121	98	79	64	52	33	19			290	16,000
4½	374	286	224	177	142	115	93	76	61	39	24			265	"
5	427	328	256	204	163	132	107	87	71	46	28			250	"
6	535	410	321	256	205	166	136	111	90	59	37	20		220	"
7	644	495	388	309	249	202	165	135	111	73	47	27		200	"
8	753	579	454	362	292	237	194	159	131	87	56	33		185	"
9	864	664	522	416	336	274	224	184	152	102	66	40	20	170	"
10	972	748	588	469	379	308	253	208	171	115	75	45	23	160	"
11	1082	834	655	523	423	345	283	233	192	130	85	52	27	150	"
12"	1193	918	723	577	466	380	312	257	212	143	94	58	30	140	"

3-9-15 "Steelcrete" Expanded Metal. Area = 0.150 sq. in. per ft. of width

Slab.	Span																Unit Stresses lbs. per sq. in.	
	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	9'-0"	10'-0"	11'-0"	12'-0"	13'-0"			Concrete	Steel.
3"	182	138	106	83	65	51	40	31	24								300	11,700
3½	262	200	155	123	98	78	63	50	40	24							"	13,300
4	356	273	214	170	137	111	91	74	60	40	25						"	14,800
4½	453	349	274	219	177	145	119	98	81	55	36	23					"	16,000
5	518	399	314	251	203	166	137	113	93	64	43	27					275	"
6	648	500	394	315	256	209	172	143	118	81	55	35	20				245	"
7	779	602	475	381	309	253	209	174	145	100	68	45	27				220	"
8	912	704	555	446	362	297	246	204	170	118	81	54	33				205	"
9	1045	808	638	512	417	343	283	236	197	138	95	64	40	21			190	"
10	1178	910	719	578	470	386	320	266	223	156	108	72	45	25			175	"
11	1313	1015	803	645	525	432	358	298	250	175	122	82	53	29			165	"
12"	1446	1119	885	711	579	476	395	329	275	194	135	91	59	33			160	"

3-9-20 "Steelcrete" Expanded Metal. Area = 0.200 sq. in. per ft. of width

Slab.	Span																Unit Stresses lbs. per sq. in	
	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	9'-0"	10'-0"	11'-0"	12'-0"	13'-0"	14'-0"	15'-0"	Concrete	Steel.
3"	201	153	118	93	73	58	46	36	29								300	9,700
3½	290	222	173	137	110	89	72	58	47	30							"	11,100
4	392	302	237	189	153	125	102	84	69	47	31						"	12,300
4½	503	389	307	246	200	164	136	113	94	65	45	29					"	13,500
5	628	486	385	310	253	208	173	144	121	86	60	41	27				"	14,600
6	869	674	536	432	354	293	245	206	174	125	90	65	45	30			290	16,000
7	1046	813	645	522	428	355	297	250	212	153	111	80	57	38	24		260	"
8	1223	951	755	611	501	416	348	293	248	180	131	95	67	46	29		240	"
9	1404	1091	868	702	576	478	400	338	286	208	152	111	80	55	36	20	220	"
10	1580	1229	977	792	649	539	452	381	323	235	172	126	90	63	41	23	210	"
11	1763	1370	1090	883	725	603	505	427	362	264	194	142	103	72	48	28	200	"
12"	1943	1511	1202	973	800	665	557	471	400	292	214	157	14	80	53	31	185	"

3-9-25 "Steelcrete" Expanded Metal. Area = 0.250 sq. in. per ft. of width

Slab.	Span															Unit Stresses lbs. per sq. in.	
	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	9'-0"	10'-0"	11'-0"	12'-0"	13'-0"	14'-0"	15'-0"	16'-0"	17'-0"		Concrete	Steel.
3"	215	164	127	100	79	63	51	40	32	19										300	8,400
3½	312	239	187	149	120	97	79	64	53	34	21									"	9,600
4	422	325	256	205	166	136	112	93	77	53	36	23								"	10,700
4½	544	421	333	267	218	179	149	124	104	73	51	35	22							"	11,700
5	677	525	416	336	274	227	189	158	133	95	68	48	33	21						"	12,700
6	977	760	605	490	402	334	280	237	201	147	108	79	57	40	27					"	14,500
7	1309	1021	814	661	545	454	383	324	277	205	153	115	86	63	45	31	19			"	16,000
8	1531	1194	953	775	639	533	449	381	325	241	181	136	102	75	54	37	24			275	"
9	1754	1369	1092	888	732	611	515	438	374	278	209	157	119	88	64	45	29			250	"
10	1982	1544	1234	1002	826	690	582	494	423	314	236	179	135	101	74	52	34	19		235	"
11	2207	1723	1375	1119	923	771	651	553	473	352	265	201	152	114	84	60	40	23		220	"
12"	2435	1897	1515	1233	1017	850	717	610	522	389	293	222	168	126	93	66	44	26		210	"

3-9-30 "Steelcrete" Expanded Metal Area = 0.300 sq. in. per ft. of width.

Slab.	Span.																			Unit Stresses lbs. per sq. in.	
	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	9'-0"	10'-0"	11'-0"	12'-0"	13'-0"	14'-0"	15'-0"	16'-0"	17'-0"	18'-0"	Concrete	Steel.
3"	226	173	134	106	85	68	54	44	35	21										300	7,400
3½	329	253	198	158	127	103	84	69	57	38	24									"	8,500
4	448	346	273	219	178	146	121	100	83	58	40	26								"	9,500
4½	576	446	353	284	232	191	159	133	112	79	56	39	26							"	10,400
5	721	560	444	359	294	243	203	171	144	104	75	54	37	25						"	11,300
6	1036	806	642	521	428	356	299	253	216	158	117	87	64	46	31	20				"	12,900
7	1405	1095	875	711	587	491	414	352	301	224	168	128	97	72	53	38	25			"	14,400
8	1808	1413	1129	921	761	637	539	459	395	296	225	172	133	102	77	57	41	27		"	15,800
9	2104	1644	1315	1072	888	744	629	537	462	347	264	204	157	121	93	70	51	35	22	280	16,000
10	2374	1855	1484	1210	1002	840	710	606	522	392	299	231	179	138	106	80	58	41	26	265	"
11	2646	2070	1657	1351	1119	938	794	678	583	439	336	259	201	156	120	91	67	47	31	245	"
12"	2920	2283	1828	1490	1234	1034	876	748	644	485	371	286	222	172	133	101	75	53	35	235	"

Slab	3-9-35 "Steelcrete" Expanded Metal. Area = 0.350 sq. in. per ft. of width — Span																		Unit Stresses lbs. per sq. in.	
	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	9'-0"	10'-0"	11'-0"	12'-0"	13'-0"	14'-0"	15'-0"	16'-0"	17'-0"	18'-0"	Concrete	Steel
3"	235	180	140	111	88	71	57	46	37	23										300	6,700
3½	343	264	207	166	134	109	89	73	60	41	26									"	7,600
4	468	361	285	229	187	153	127	106	88	62	43	29								"	8,600
4½	606	470	372	300	246	203	169	142	119	85	61	43	29							"	9,400
5	756	588	467	377	309	257	215	181	153	111	81	58	41	28						"	10,300
6	1092	851	678	551	454	378	318	269	230	169	126	94	70	51	36	24				"	11,700
7	1473	1151	919	748	618	517	436	371	318	237	180	137	104	79	59	43	29			"	13,000
8	1907	1490	1193	972	805	674	571	487	419	315	240	185	143	111	85	64	47	33	21	"	14,300
9	2374	1858	1489	1215	1008	846	718	614	529	400	308	239	187	147	115	89	68	50	36	"	15,500
10	2762	2164	1733	1415	1174	986	837	717	618	468	361	282	221	174	137	107	83	62	45	290	16,000
11	3083	2414	1935	1580	1311	1101	935	801	691	525	405	316	249	197	155	122	94	71	52	270	"
12"	3400	2660	2135	1744	1446	1215	1032	884	764	579	447	350	275	218	172	135	105	80	59	255	"

Slab	3-6-40 "Steelcrete" Expanded Metal Area = 0.400 sq. in. per ft. of width — Span.																		Unit Stresses lbs. per sq. in.	
	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	9'-0"	10'-0"	11'-0"	12'-0"	13'-0"	14'-0"	15'-0"	16'-0"	17'-0"	18'-0"	Concrete	Steel.
3"	244	186	145	115	92	74	60	49	39	25										300	6,100
3½	355	273	215	171	139	113	93	77	63	43	28									"	7,000
4	484	374	296	238	194	160	132	110	92	65	46	31	20							"	7,800
4½	628	487	387	312	256	211	176	148	125	90	64	46	32	21						"	8,600
5	787	612	486	394	323	268	225	190	161	117	86	62	45	31	20					"	9,400
6	1138	887	708	574	474	395	332	282	241	178	133	100	75	55	40	27				"	10,800
7	1541	1203	961	783	648	542	458	390	335	251	190	146	112	85	64	47	33	22		"	12,000
8	1988	1555	1245	1016	841	705	597	511	440	331	254	196	153	119	92	70	52	37	25	"	13,200
9	2479	1942	1556	1270	1054	886	752	644	556	421	325	253	199	157	123	96	74	56	41	"	14,300
10	3019	2364	1897	1551	1287	1083	921	790	683	519	402	316	250	199	158	125	99	76	58	"	15,400
11	3510	2753	2210	1808	1501	1264	1075	923	799	609	473	373	297	237	190	152	121	95	73	295	16,000
12"	3870	3035	2435	1995	1657	1395	1187	1018	881	673	523	412	328	262	210	169	134	106	82	280	"

Slab	3-6-45 "Steelcrete" Expanded Metal Area = 0.450 sq. in. per ft of width — Span																		Unit Stresses. lbs. per sq. in.	
	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	9'-0"	10'-0"	11'-0"	12'-0"	13'-0"	14'-0"	15'-0"	16'-0"	17'-0"	18'-0"	Concrete	Steel.
3"	251	192	150	119	95	77	62	51	41	26										300	5,600
3½	366	282	222	177	144	117	97	80	66	45	30	19								"	6,400
4	500	386	306	246	201	165	138	115	96	69	48	33	22							"	7,200
4½	649	503	400	323	264	219	183	154	130	94	68	49	34	22						"	8,000
5	812	632	503	407	335	278	233	197	167	122	90	66	48	33	22					"	8,700
6	1182	922	736	598	493	412	347	295	252	187	140	106	80	59	43	30	20			"	10,000
7	1604	1253	1003	817	676	566	479	408	351	263	201	154	119	91	69	52	37	26		"	11,200
8	2065	1616	1294	1056	875	735	623	532	459	347	266	206	161	126	98	75	57	42	29	"	12,200
9	2579	2019	1619	1324	1099	923	784	672	580	440	340	266	210	166	132	103	80	62	46	"	13,300
10	3139	2459	1974	1614	1342	1129	959	824	713	543	422	332	264	210	168	134	106	83	64	"	14,300
11	3735	2930	2355	1925	1601	1350	1149	988	855	654	509	403	322	259	209	168	135	108	85	"	15,200
12"	4345	3405	2738	2245	1867	1575	1340	1154	1000	766	599	475	380	307	249	202	164	132	105	"	16,000

Slab	3-6-50 "Steelcrete" Expanded Metal. Area = 0.500 sq. in. per ft. of width. — Span.																		Unit Stresses lbs. per sq. in.	
	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	9'-0"	10'-0"	11'-0"	12'-0"	13'-0"	14'-0"	15'-0"	16'-0"	17'-0"	18'-0"	Concrete	Steel.
4"	513	397	315	253	207	171	142	119	100	71	50	35	23							300	6,700
4½	667	518	411	332	272	226	189	159	134	97	71	51	36	24						"	7,400
5	834	650	517	419	344	286	240	203	173	126	93	69	50	36	24					"	8,100
6	1216	949	758	616	508	425	358	305	261	194	146	111	84	63	46	33	22			"	9,300
7	1653	1291	1033	843	697	584	494	422	363	273	208	160	124	96	73	55	40	28		"	10,400
8	2143	1678	1344	1097	910	763	648	555	478	362	278	217	170	133	104	81	62	46	33	"	11,500
9	2674	2094	1679	1374	1140	959	815	698	604	459	355	279	220	175	139	110	86	67	50	"	12,500
10	3244	2544	2044	1671	1389	1169	995	854	740	564	438	346	275	220	177	142	113	89	69	"	13,400
11	3865	3035	2435	1995	1660	1398	1192	1025	888	679	531	420	336	271	219	177	143	115	91	"	14,300
12"	4535	3560	2860	2345	1952	1645	1403	1207	1047	803	629	500	401	325	265	216	176	142	115	"	15,100

3-6-55 "Steelcrete" Expanded Metal Area=0.550 sq. in. per ft. of width																				Unit Stresses lbs. per sq. in.	
Slab.	Span.																				
	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	9'-0"	10'-0"	11'-0"	12'-0"	13'-0"	14'-0"	15'-0"	16'-0"	17'-0"	18'-0"	Concrete	Steel.
4"	450	347	274	220	179	147	121	101	84	57	40	26								300	5,900
4½	599	464	368	297	242	200	167	140	117	84	60	42	28							"	6,600
5	765	594	472	382	313	260	217	183	155	113	82	59	42	29						"	7,300
6	1143	892	711	578	476	397	334	284	242	179	134	101	75	56	40	27				"	8,400
7	1584	1238	989	807	667	559	473	403	346	259	197	151	117	89	68	50	36	24		"	9,500
8	2073	1623	1299	1061	879	738	625	535	461	348	267	207	162	127	99	76	57	42	29	"	10,600
9	2609	2044	1639	1339	1112	935	794	681	588	446	345	270	213	169	134	106	82	63	47	"	11,500
10	3194	2504	2011	1644	1367	1150	979	840	728	554	430	339	270	216	173	138	110	86	67	"	12,400
11	3815	2993	2405	1968	1638	1380	1175	1010	875	669	522	413	331	266	215	174	140	112	89	"	13,200
12"	4505	3535	2840	2327	1937	1635	1393	1198	1040	797	624	496	398	322	262	213	174	141	113	"	14,000

3-6-60 "Steelcrete" Expanded Metal Area = 0.600 sq. in. per ft. of width.																				Unit Stresses lbs. per sq. in.	
Slab.	Span																				
	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	9'-0"	10'-0"	11'-0"	12'-0"	13'-0"	14'-0"	15'-0"	16'-0"	17'-0"	18'-0"	Concrete	Steel.
4"	459	354	280	225	183	150	124	103	86	60	41	28								300	5,600
4½	612	475	376	304	248	205	171	143	121	86	62	44	30	19						"	6,200
5	780	607	482	390	320	266	223	188	159	116	85	62	44	30	20					"	6,800
6	1171	913	728	592	488	408	344	292	249	185	139	105	79	58	42	29	19			"	8,000
7	1622	1266	1013	826	683	573	485	413	355	266	203	156	121	93	71	53	39	27		"	9,000
8	2128	1665	1334	1089	903	759	643	551	475	359	276	215	168	132	103	80	61	45	32	"	10,000
9	2684	2103	1686	1379	1144	963	819	702	606	461	357	280	222	176	140	111	87	67	51	"	10,900
10	3284	2576	2069	1693	1407	1184	1008	866	749	572	445	351	280	224	180	144	115	91	71	"	11,700
11	3935	3085	2480	2032	1690	1425	1213	1044	905	693	541	429	344	277	225	182	147	119	94	"	12,500
12"	4620	3625	2915	2387	1987	1677	1430	1231	1068	820	642	511	411	333	271	222	181	147	119	"	13,300

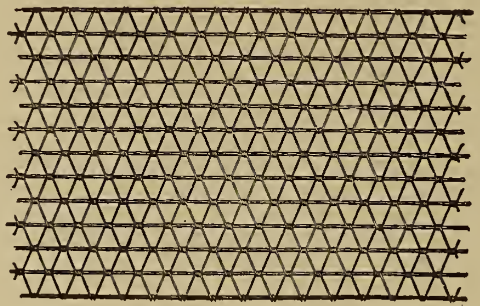
Adjoining sheets should be lapped 8″ on the end and one and one-half inches on the side. They should be wired together every three feet on the ends and every four feet on the sides.

A reinforcing fabric known as the Triangle Mesh Concrete Reinforcement is manufactured by the American Steel and Wire Co.

The tables which follow have been copied from an Engineer's Handbook published by the Company.

This triangle mesh steel woven wire is made with both single and stranded longitudinal, or tension members. That with the single wire longitudinal is made with one wire varying in size from a No. 12 gauge up to and including a ½″ dia., and that with the standard longitudinal is composed of two or three wires varying from No. 12 gauge up to and including No. 4 wires stranded or twisted together.

These longitudinals either stranded or solid are invariably spaced 4″ centres, the sizes being varied in order to obtain the desird cross-sectional area of steel per foot of width. (See illustration.)



Area of Steel Required per Foot of Width for a Maximum Resisting Moment of Slab of Given Thickness

Corresponding SAFE BENDING MOMENT due to applied load and weight of floor:

$$M = \frac{wl^2}{10} = \frac{1}{10} \times \text{Load per sq. ft.} \times (\text{length of span})^2 = \text{Bending Moment for slab supported on two sides.}$$

$$M = \frac{wl^2}{20} = \text{Bending Moment.}$$

The Maximum Allowable Fiber Stress in the steel governs the values of Resisting Moments given below and to the left of the heavy zigzag line; the Maximum Allowable Fiber Stress in the concrete governs the values above and to the right of this line.

For example showing use of tables see page 69

Maximum Stresses: Steel = 16,000 pounds, Concrete = 650 pounds — Conc. { 1:2: 4 / 1:2½:5 carefully graded

Total Thickness of Slab Inches	Center of Steel to Bot. of Slab	Weight of Slab per sq. ft. Pounds	MOMENTS OF RESISTANCE IN FOOT POUNDS PER FOOT OF WIDTH																						
			CROSS SECTIONAL AREA IN SQUARE INCHES OF STEEL REINFORCEMENT PER FOOT OF WIDTH																						
			.04	.06	.08	.10	.12	.14	.16	.18	.20	.25	.30	.35	.40	.45	.50	.55	.60	.65	.70	.75	.80	.90	1.00
2½	¾	30	86	130	168	210	248	289	325	341	353	377													
3	¾	36	114	165	222	271	327	375	423	478	525	578	611												
3½	¾	42	137	203	268	332	395	458	520	592	653	804	858	900											
4	¾	48	160	237	329	404	478	552	625	697	769	954	1136	1194	1246										
4½	¾	54	192	275	377	458	557	636	734	812	890	1100	1327	1519	1585	1644									
5	1	60		313	407	498	589	679	769	858	968	1187	1403	1637	1764	1835	1893								
5½	1	66		337	455	572	659	774	888	973	1086	1337	1612	1857	2099	2232	2314	2381							
6	1	72			489	634	742	849	991	1095	1201	1513	1787	2058	2359	2625	2756	2848	2922						
6½	1	78			547	678	811	941	1071	1199	1327	1664	1957	2286	2612	2895	3216	3334	3431	3525					
7	1	84				756	913	1017	1172	1326	1478	1831	2179	2524	2866	3157	3541	3872	3968	4072	4169	4259			
7½	1¼	90				764	934	1103	1216	1383	1548	1877	2257	2632	2951	3320	3686	3998	4255	4371	4464	4566			
8	1¼	96					1023	1156	1352	1483	1678	2062	2443	2820	3257	3627	3995	4360	4723	4963	5080	5207	5309	5498	5668
8½	1¼	102					1104	1257	1409	1636	1786	2232	2673	3037	3470	3900	4256	4679	5100	5519	5725	5860	5987	6201	6410
9	1½	108						1346	1508	1670	1831	2309	2703	3172	3560	4021	4479	4857	5308	5683	6077	6200	6340	6576	6788
9½	1½	114						1437	1623	1807	1992	2447	2897	3343	3874	4313	4749	5182	5612	6125	6550	6914	7055	7338	7571
10	1½	120							1728	1936	2144	2660	3068	3573	4075	4572	5066	5557	6044	6529	7011	7395	7836	8114	8393

Maximum Stresses: Steel = 16,000 pounds, Concrete = 700 pounds — Conc. 1:2:4

Total Thickness of Slab Inches	Center of Steel to Bot. of Slab	Weight of Slab per sq. ft. Pounds	MOMENTS OF RESISTANCE IN FOOT POUNDS PER FOOT OF WIDTH																						
			CROSS SECTIONAL AREA IN SQUARE INCHES OF STEEL REINFORCEMENT PER FOOT OF WIDTH																						
			.04	.06	.08	.10	.12	.14	.16	.18	.20	.25	.30	35	.40	.45	.50	.55	.60	.65	.70	.75	.80	.90	1.00
2½	¾	30	86	130	168	210	248	289	325	366	379	406													
3	¾	36	114	165	222	271	327	375	423	478	525	623	658												
3½	¾	42	137	203	268	332	395	458	520	592	653	804	924	969											
4	¾	48	160	237	329	404	478	552	625	697	769	954	1137	1286	1342										
4½	¾	54	192	275	377	458	557	636	734	812	890	1100	1327	1532	1707	1770									
5	1	60		313	407	498	589	679	769	858	968	1187	1403	1637	1849	1976	2038								
5½	1	66		337	455	572	659	774	888	973	1086	1337	1612	1857	2099	2340	2492	2565							
6	1	72			489	634	742	849	991	1095	1201	1513	1787	2058	2359	2625	2889	3066	3147						
6½	1	78			547	678	811	941	1071	1199	1327	1664	1957	2286	2612	2895	3216	3495	3698	3796					
7	1	84				756	913	1017	1172	1326	1478	1831	2179	2524	2866	3157	3541	3875	4160	4386	4490	4586			
7½	1¼	90				764	934	1103	1216	1383	1548	1877	2257	2632	2951	3320	3686	3998	4359	4704	4802	4913			
8	1¼	96					1023	1156	1352	1483	1678	2062	2443	2820	3257	3627	3995	4360	4723	5084	5444	5607	5717	5920	6104
8½	1¼	102					1104	1257	1409	1636	1786	2232	2673	3037	3470	3900	4256	4679	5100	5519	5866	6280	6447	6678	6903
9	1½	108						1346	1508	1670	1831	2309	2703	3172	3560	4021	4479	4857	5308	5683	6129	6500	6828	7081	7310
9½	1½	114						1437	1623	1807	1992	2447	2897	3343	3874	4313	4749	5182	5612	6125	6550	6973	7395	7902	8154
10	1½	120							1728	1936	2144	2660	3068	3573	4075	4572	5066	5557	6044	6529	7011	7395	7968	8739	9038

Maximum Stresses: Steel = 18,000 pounds, Concrete = 700 pounds — Conc. 1:2:4

Total Thickness of Slab Inches	Center of Steel to Bot. of Slab	Weight of Slab per sq. ft. Pounds	MOMENTS OF RESISTANCE IN FOOT POUNDS PER FOOT OF WIDTH																						
			CROSS SECTIONAL AREA IN SQUARE INCHES OF STEEL REINFORCEMENT PER FOOT OF WIDTH																						
			.04	.06	.08	.10	.12	.14	.16	.18	.20	.25	.30	.35	.40	.45	.50	.55	.60	.65	.70	.75	.80	.90	1.00
2½	¾	30	97	146	189	237	279	325	353	367	379	406													
3	¾	36	128	185	250	305	368	422	476	537	579	623	658												
3½	¾	42	154	228	301	373	444	515	585	666	734	872	924	969											
4	¾	48	180	267	370	454	538	621	703	784	865	1074	1223	1286	1342										
4½	¾	54	216	309	424	515	627	716	826	914	1001	1238	1493	1636	1707	1770									
5	1	60		352	456	560	663	764	865	965	1090	1336	1578	1821	1899	1976	2038								
5½	1	66		379	512	644	741	871	999	1095	1222	1504	1814	2089	2316	2404	2492	2565							
6	1	72			550	714	835	956	1115	1234	1352	1702	2010	2315	2654	2871	2968	3066	3147						
6½	1	78			616	765	913	1059	1206	1349	1493	1872	2200	2571	2938	3257	3489	3591	3698	3796					
7	1	84				851	1027	1144	1318	1491	1663	2059	2452	2840	3225	3551	3984	4170	4274	4386	4490	4586			
7½	1¼	90				859	1050	1240	1366	1554	1741	2110	2537	2959	3318	3735	4143	4442	4579	4704	4802	4913			
8	1¼	96					1152	1300	1522	1668	1887	2320	2749	3173	3664	4081	4494	4905	5210	5345	5470	5607	5717	5920	6104
8½	1¼	102					1243	1414	1586	1840	2009	2511	3006	3416	3906	4386	4789	5264	5738	6035	6166	6311	6447	6678	6903
9	1½	108						1514	1697	1879	2059	2598	3041	3569	4004	4524	5038	5464	5972	6373	6544	6677	6828	7081	7310
9½	1½	114						1618	1827	2034	2240	2753	3259	3761	4358	4852	5342	5830	6313	6890	7284	7446	7597	7902	8154
10	1½	120							1944	2180	2413	2993	3451	4020	4584	5144	5700	6252	6810	7345	7889	8224	8440	8739	9038

LONGITUDINALS SPACED 4-INCH CENTERS
CROSS WIRES SPACED 4-INCH CENTERS

Number and Gauge of Wires, Areas Per Foot Width and Weights Per 100 Square Feet
Styles Marked * Usually Carried in Stock.

Style Number	No. of Wires Each Long	Gauge of Wire Each Long	Gauge of Cross Wires	Sectional Area Long. Sq. In.	Sectional Area Cross Wires	Cross Sectional Area per Ft. Width	Approximate Weight per 100 Sq. Ft.
* 4	1	6	14	.087	.025	.102	43
5	1	8	14	.062	.025	.077	34
6	1	10	14	.043	.025	.058	27
* 7	1	12	14	.026	.025	.041	21
*23	1	1/4"	12½	.147	.038	.170	72
24	1	4	12½	.119	.038	.142	62
25	1	5	12½	.101	.038	.124	55
*26	1	6	12½	.087	.038	.110	50
*27	1	8	12½	.062	.038	.085	41
28	1	10	12½	.043	.038	.066	34
29	1	12	12½	.026	.038	.049	28
31	2	4	12½	.238	.038	.261	106
32	2	5	12½	.202	.038	.225	92
33	2	6	12½	.174	.038	.196	82
34	2	8	12½	.124	.038	.146	63
35	2	10	12½	.086	.038	.109	50
36	2	12	12½	.052	.038	.075	37
*38	3	4	12½	.358	.038	.380	151
39	3	5	12½	.303	.038	.325	130
40	3	6	12½	.260	.038	.283	114
41	3	8	12½	.185	.038	.208	87
*42	3	10	12½	.129	.038	.151	66
43	3	12	12½	.078	.038	.101	47

LENGTH OF ROLLS: 150-ft., 300-ft. and 600-ft.
WIDTHS: 18-in., 22-in., 26-in., 30-in., 34-in., 38-in., 42-in., 46-in., 50-in., 54-in. and 58-in.

LONGITUDINAL SPACED 4-INCH CENTERS
CROSS WIRES SPACED 2-INCH CENTERS

Number and Gauge of Wires, Areas Per Foot Width and Weights Per 100 Square Feet
Styles Marked * Usually Carried in Stock

Style Number	No. of Wires Each Long	Gauge of Wire Each Long	Gauge of Cross Wires	Sectional Area Long. Sq. In.	Sectional Area Cross Wires Sq. In.	Cross Sectional Area per Ft. Width	Approximate Weight per 100 Sq. Ft.
4-A	1	6	14	.087	.050	.102	53
5-A	1	8	14	.062	.050	.077	44
6-A	1	10	14	.043	.050	.058	37
* 7-A	1	12	14	.026	.050	.041	31
23-A	1	1/4"	12½	.147	.076	.170	86
24-A	1	4	12½	.119	.076	.142	76
25-A	1	5	12½	.101	.076	.124	70
26-A	1	6	12½	.087	.076	.110	64
27-A	1	8	12½	.062	.076	.085	55
*28-A	1	10	12½	.043	.076	.066	48
29-A	1	12	12½	.026	.076	.049	42
31-A	2	4	12½	.238	.076	.261	120
32-A	2	5	12½	.202	.076	.225	107
33-A	2	6	12½	.174	.076	.196	97
34-A	2	8	12½	.124	.076	.146	78
35-A	2	10	12½	.086	.076	.109	64
36-A	2	12	12½	.052	.076	.075	52
38-A	3	4	12½	.358	.076	.380	165
39-A	3	5	12½	.303	.076	.325	145
40-A	3	6	12½	.260	.076	.283	129
41-A	3	8	12½	.185	.076	.208	101
42-A	3	10	12½	.129	.076	.151	81
43-A	3	12	12½	.078	.076	.101	62

LENGTH OF ROLLS: 150-ft., 300-ft. and 600-ft.
WIDTHS: 18-in., 22-in., 26-in., 30-in., 34-in., 38-in., 42-in., 46-in., 50-in., 54-in. and 58-in.

This table taken from the Engineer's Handbook gotten out by the American Steel and Wire Co. contains information which may be of use.

Mixtures			Required for 1 cubic yard rammed concrete								
			Stone 1 in. and under, dust screened out			Stone. 2½ in. and under, dust screened out			Gravel ¾ in. and under		
Cement	Sand	Stone	Cement, bbls.	Sand, cu. yds.	Stone, cu. yds.	Cement, bbls.	Sand, cu. yds.	Stone, cu. yds.	Cement, bbls.	Sand, cu. yds.	Gravel, cu. yds.
1	1.0	2.0	2.57	0.39	0.78	2.63	0.40	0.80	2.30	0.35	0.74
1	1.0	2.5	2.29	0.35	0.70	2.34	0.36	0.89	2.10	0.32	0.80
1	1.0	3.0	2.06	0.31	0.94	2.10	0.32	0.96	1.89	0.29	0.86
1	1.0	3.5	1.84	0.28	0.98	1.88	0.29	1.00	1.71	0.26	0.91
1	1.5	2.5	2.05	0.47	0.78	2.09	0.48	0.80	1.83	0.42	0.73
1	1.5	3.0	1.85	0.42	0.84	1.90	0.43	0.87	1.71	0.39	0.78
1	1.5	3.5	1.72	0.39	0.91	1.74	0.40	0.93	1.57	0.36	0.83
1	1.5	4.0	1.57	0.36	0.96	1.61	0.37	0.98	1.46	0.33	0.88
1	1.5	4.5	1.43	0.33	0.98	1.46	0.33	1.00	1.34	0.31	0.91
1	2.0	3.0	1.70	0.52	0.77	1.73	0.53	0.79	1.54	0.47	0.73
1	2.0	3.5	1.57	0.48	0.83	1.61	0.49	0.85	1.44	0.44	0.77
1	2.0	4.0	1.46	0.44	0.89	1.48	0.45	0.90	1.34	0.41	0.81
1	2.0	4.5	1.36	0.42	0.93	1.38	0.42	0.95	1.26	0.38	0.86
1	2.0	5.0	1.27	0.39	0.97	1.29	0.39	0.98	1.17	0.36	0.89
1	2.5	3.5	1.45	0.55	0.77	1.48	0.56	0.79	1.32	0.50	0.70
1	2.5	4.0	1.35	0.52	0.82	1.38	0.53	0.84	1.24	0.47	0.75
1	2.5	4.5	1.27	0.48	0.87	1.29	0.49	0.88	1.16	0.44	0.80
1	2.5	5.0	1.19	0.46	0.91	1.21	0.46	0.92	1.10	0.42	0.83
1	2.5	5.5	1.13	0.43	0.94	1.15	0.44	0.96	1.03	0.39	0.86
1	2.5	6.0	1.07	0.41	0.97	1.07	0.41	0.98	0.98	0.37	0.89
1	3.0	4.0	1.26	0.58	0.77	1.28	0.58	0.78	1.15	0.52	0.72
1	3.0	4.5	1.18	0.54	0.81	1.20	0.55	0.82	1.09	0.50	0.75
1	3.0	5.0	1.11	0.51	0.85	1.14	0.52	0.87	1.03	0.47	0.78
1	3.0	5.5	1.06	0.48	0.89	1.07	0.49	0.90	0.97	0.44	0.81
1	3.0	6.0	1.01	0.46	0.92	1.02	0.47	0.93	0.92	0.42	0.84
1	3.0	6.5	0.96	0.44	0.95	0.98	0.44	0.96	0.88	0.40	0.87
1	3.0	7.0	0.91	0.42	0.97	0.92	0.42	0.98	0.84	0.38	0.89
1	3.5	5.0	1.05	0.56	0.80	1.07	0.57	0.82	0.96	0.50	0.76
1	3.5	5.5	1.00	0.53	0.84	1.02	0.54	0.85	0.92	0.48	0.78
1	3.5	6.0	0.95	0.50	0.87	0.97	0.51	0.89	0.88	0.46	0.80
1	3.5	6.5	0.92	0.49	0.91	0.93	0.49	0.92	0.83	0.44	0.82
1	3.5	7.0	0.87	0.47	0.93	0.89	0.47	0.95	0.80	0.43	0.85
1	3.5	7.5	0.84	0.45	0.96	0.86	0.45	0.98	0.76	0.41	0.87
1	3.5	8.0	0.80	0.42	0.97	0.82	0.43	1.01	0.73	0.39	0.89
1	4.0	6.0	0.90	0.55	0.82	0.92	0.56	0.84	0.83	0.51	0.77
1	4.0	6.5	0.87	0.53	0.85	0.88	0.53	0.87	0.80	0.49	0.79
1	4.0	7.0	0.83	0.51	0.89	0.84	0.51	0.90	0.77	0.47	0.81
1	4.0	7.5	0.80	0.49	0.91	0.81	0.50	0.93	0.73	0.44	0.83
1	4.0	8.0	0.77	0.47	0.93	0.78	0.48	0.95	0.71	0.43	0.86
1	4.0	8.5	0.74	0.45	0.95	0.76	0.46	0.98	0.68	0.42	0.88
1	4.0	9.0	0.71	0.43	0.97	0.73	0.44	1.01	0.65	0.40	0.89

1 bbl. cement & 2 bbl. sand will cover 99 sq. ft. of floor 1 in. thick.
1 " " 1 " " " " 68 " " " " 1 " "

COSTS

To give an idea as to the relative costs of the different items entering into the total cost of a Power House two tables have been given. It is seen from these tabulations that the total cost per K. W. exclusive of the land is around $105 for a station of moderate size and goes as low as $60 for large stations.

In one station the cost of piping may be greater than that in another of the same size. This may be offset, however, by the lower cost of some other item so that the total cost of the two does not differ much.

POWER HOUSE COST PER RATED K. W. INSTALLED	Max.	Min.
Foundations	$3.50	$1.50
Sidings, roadways, circulating water intake and discharge and buildings	15.00	8.00
Chimneys and flues	3.50	2.50
Building Total	$22.50	$12.50
Boilers, installed	14.00	8.00
Superheater	1.50	1.00
Stokers	10.00	4.00
Economizers	5.00	3.00
Coal Conveyor and bunkers	6.00	2.00
Ash conveyor	1.50	1.00
Piping and pipe covering	12.00	6.00
Feed pumps	1.00	1.00
Feed water heater	2.00	1.00
Turbine and generator	15.00	12.00
Condenser, jet type	3.00	2.50
Exciter	1,50	.75
Switchboard	4.00	2.50
Cables and conduits in power house	6.00	3.00
Incidentals	2.00	2.00
Machinery Total	$84.50	$48.75
Grand Total	106.50	60.25

Koester in Steam Electric Power Plants gives the following tabulations of costs for plants of 3000 to 5000 K.W. capacity.

COST OF TURBINE PLANTS 3000 to 5000 K. W. — per K. W.	Min.	Max.
Excavations and Foundations	$2.00	$2.50
Building	10.00	15.00
Tunnels	1.75	4.00
Flues and Stacks	2.50	3.50
Boilers and Stokers	8.50	12.00
Superheaters	2.00	2.50
Economizers	2.00	2.25
Coal and Ash System	1.50	3.00
Blowers and Ducts	1.00	1.50
Pumps and Tanks	1.00	1.25
Piping complete	2.25	4.50
Turbo-Generators	22.00	25.00
Condensers — surface	5.00	8.00
Exciters	.75	1.00
Cranes	.25	.50
Switchboard	2.00	3.50
Labor and Incidentals	1.00	2.00
	$65.00	$92.00

COST OF EXCAVATION FOR FOUNDATIONS

Cost per cubic yard

		Ledge	Good° Gravel	Good° Sand	Good* Clay	Poor Sand or dry crib Work	Pile on† wet clay or Sand
1st	5 ft.	2.00	0.40	0.30	0.25	0.50	0.60
2nd.	5 ft.	2.75	0.60	0.50	0.35	0.70	0.75
3rd.	5 ft.	3.50	0.80	0.70	0.80	1.00	1.50

° Some bracing of banks required.
* No bracing of banks required (large quantities excavated).
† Average for 15 feet depth without sheet piling $0.90.

Average for 15 feet depth with sheet piling $1.00.
Rock excavation $2.00 to $3.00 per cu. yd.
Cement costs from $1.30 to $1.50 per bbl.
Sand costs $1.00 per cu. yd. delivered.
Stone costs $1.00 per cu. yd. at crusher.
Concrete footings concrete alone costs $7.20 per cu. yd.
Forms cost about 12 cents a sq. ft.

A rough estimate of the cost of a footing including excavation, concrete and forms may be made by figuring the concrete at $9.00 per cubic yard.

PILES

Oak piles 20-30 ft. long 12″ butt 6″ top, 17 cents per ft. of length.
Oak piles 40-60 ft. long, 21 to 25 cents per ft. of length.
Spruce piles 20-30 ft. long 10″ butt, 15 cents per ft. of length.
Cost of driving and cutting off, 9 cents per ft. of length.
Concrete piles in place from $1.25 to $1.50 per ft. of length.

BRICKS

Bricks per 1000, $7.50 to $10.00.

Cost of laying 1000 bricks in a wall 10″to 12″ thick including mason, helper and staging is $8 to $8.50. 1000 bricks laid make 2 cu. yds. masonry and cost $16 to $18.

CONCRETE WALLS AND FLOORS

Concrete forms for floors, 12 cts. per sq. ft.
Concrete forms for walls (2 sides) 24 cents sq. ft. wall area.
Concrete wall 6″ thick including forms, costs, 40 cents per sq. ft.
Concrete, $7.20 cu. yard.

If there is no abnormal amount of reinforcement the cost of a floor may be figured by adding the cost of the form 12 cents per sq. ft. to the cost of the concrete per sq. ft. which is $.0222 × thickness of floor in inches.

Where there is an abnormal amount of reinforcement the cost of the steel should be considered.

STEEL FRAMEWORK

The cost of structural steel work varies with the price of steel and fluctuates between $45 and $75 per ton erected.

In general $60 a ton is a safe figure to use.

FLUES, DAMPERS, ETC.

Flues should be figured by the cost per pound. A flue (⅛″ thick) without difficult bends may be estimated at 10 cents per pound erected. A flue may cost as much as 15 cents a pound where there is difficulty in erecting it on account of lack of space.

BOILERS

A high pressure water tube boiler
400 to 800 H. P. per unit, $16.50 H. P. erected.
Superheater for same, $1.50 to $1.00 per H. P.

ECONOMIZERS

Economizers $10 to $12 per tube erected or about $4.50 per Boiler Horse Power.

STOKERS

Stokers cost from $6 to $10 per rated H. P. of boiler.

CHIMNEYS

The cost of Radial Brick Chimneys is approximately as given below.
These costs being for the structure above the foundations.

Height				Top diams. in ft.			
Ft.	4	6	8	10	12	14	16
75	1400	2000	2700	3700			
125		3500	4300	4700	5100		
150			6200	7200	7800	8300	
175			7000	8000	9000	9800	
200				10500	11000	12500	
250				16500	18300	22000	24300

The comparative total costs of a chimney 150 ft. tall 8 ft. diam. as given by Christie in "Chimney Design and Theory" are:

Red brick	$8500
Radial brick	$6800
Steel, self supporting full lined	$8300
Steel, self supporting half lined	$7800
Steel, self supporting unlined	$5820
Steel guyed	$4000

COAL CONVEYOR

For a station of 15000 K. W. capacity about $1.15 per K.W.; for 5000 K.W. about $2.50; for 1000 K. W. about $4.00 per K. W.

COAL BUNKERS

For parabolic form estimate steel if of suspended type, rods or straps as $100 per ton erected, if of steel plate $75 per ton erected. Add to this the cost of the concrete lining.

If of girder type figure steel as $65 per ton and add cost of concrete.

TURBINES AND GENERATORS

Price depends upon market conditions but generally around $13 K. W.

Some quotations obtained in February, 1915, at a time when steel was low in price were as follows:

	Turbine and Generator	
G. E. Co.	2000 K. W.	$23,000
	2000 K. W. bleeder type	$24,000
	1000 K. W.	$13,500
Westinghouse	2000	$18,500
	2000 bleeder	$19,500
	1000	$13,000
A Le Blanc condenser for the		
2000 K. W. cost		$4250
1000 K. W. cost		$2800

A cooling tower for 3000 K. W. 26″ vacuum $7,800 above foundation.

COMPARISON OF COSTS OF DIFFERENT TYPES OF ENGINES*

Cylinders	Speed	Exhaust	Steam Consumption Lbs. per I. H. P. hr. non cond'g	cond'g	Cost per H. P. Engine erected	Bldgs. Boilers Chimney	Total cost
Simple	High speed	Non-cond'g	33	—	$17.50	$15.20	$32.70
	High speed	Cond'g	—	22	21.00	12.00	33.00
	Low speed	Non-cond'g	29	—	25.00	14.20	39.20
	Low speed	Cond'g	—	20	27.00	11.50	38.50
Compound	High speed	Non-cond'g	26	—	21.00	13.10	34.60
	High speed	Cond'g	—	20	24.50	11.40	35.90
	Low speed	Cond'g	—	18	30.00	11.00	41.00
Triple Exp.	High speed	Non-cond'g	24	—	26.00	12.50	38.50
	High speed	Cond'g	—	17	29.00	10.50	39.50
	Low speed	Cond'g	—	16	37.50	10.30	47.80

*From Mr. Chas. E. Emery.

The following pages giving the Cost of Steam and Power Plant Equipment were taken from an Article by Professor A. A. Potter, M. I. T. 1903, in *Power*, December 30, 1913.

TABLE OF COSTS OF STEAM AND GAS POWER-PLANT EQUIPMENT

Name of Apparatus	Type	Capacity	Equation of Cost in Dollars
Air compressors	Single cylinder, belt-driven	Up to 4000 cu. ft. per min.	52 + 1.95 × cu. ft.
	Duplex, belt-driven	Up to 850 cu. ft. per min.	316 + 1.675 × cu. ft.
	Compound, belt-driven	Up to 550 cu. ft. per min.	3.1 × cu. ft.
	Single cylinder, steam-driven	Up to 350 cu. ft. per min.	231 + 2.32 × cu. ft.
	Duplex, steam-driven	Up to 600 cu. ft. per min.	460 + 2.55 × cu. ft.
	Compound, steam-driven	Up to 500 cu. ft. per min.	71.25 + 4.025 × cu. ft.
Boilers, steam	Vertical, fire-tube	Under 20 hp.	49.2 + 6.66 × hp.
	Submerged tubes, 100 lb. per sq. in. or less	20 to 50 hp.	116.4 + 3.35 × hp.
	Full length tubes; 100 lb. per sq. in. or less	Up to 50 hp.	51.5 + 3.62 × hp.
	Horizontal, fire-tube cylindrical, multitubular, 100 lb. per sq. in. or less	Up to 200 hp.	64 + 4.14 × hp.
		Up to 100 hp.	5.8 × hp. − 20
		100 hp. to 225 hp.	211 + 3.35 × hp.
	Portable locomotive	Up to 100 hp.	121 + 5.68 × hp.
	Vertical, water-tube, pressures over 125 lb. per sq. in.	100 to 500 hp.	912 + 6.28 × hp.
	Horizontal, water-tube, pressures over 125 lb. per sq. in.	100 to 600 hp.	149 + 8.24 × hp.
Condensers	Barometric (28-in. vacuum)	Up to 30,000 lb. of steam per hr.	1055 + 0.112 × (lb. steam cond.)
	Jet condensers	Up to 30,000 lb. of steam per hour; 28-in vacuum.	1176 + 0.1138 × (lb. steam cond.)
		26-in. vacuum	116 + 0.0591 × (lb. steam cond.)
	Surface condensers	Up to 35,000 lb. of steam per hr.; 28-in. vacuum	1630 + 0.2038 × (lb. steam cond.)
		Up to 30,000 lb. of steam per hr.; 26-in. vacuum	413 + 0.1015 × (lb. steam cond.)
Economizers	Number of tubes 32 to 10,000, heating surface per tube = 12 to 13 sq. ft.	Capacity in lb. of water per tube = 60 to 70	
		Economizer alone	$8 to $10 per tube
		Economizer erected	$12 to $15 per tube
Engines, internal combustion	Gas engines	Up to 300 hp.	33.6 × hp. − 115
	Gasoline engines, hit-and-miss governor	Up to 100 hp.	141 + 24.8 × hp.
	Gasoline engines, throttling governor	Up to 75 hp.	309 + 36.1 × hp.
	Oil engines	Up to 400 hp.	63.8 × hp. − 316
	Producer gas engines, American mfg.	Up to 300 hp.	400 + 33.5 × kp.
Engines, steam	Simple,		
	Throttling governor, slide valve, vertical	Up to 70 hp.	63.5 + 17.5 × hp.
	Throttling governor, slide valve, horizontal,		
	Upper limit in cost	Up to 70 hp.	107 + 13.3 × hp.
	Lower limit in cost	Up to 200 hp.	80 + 5.81 × hp.
	Simple,		
	Flywheel governor, piston or balanced slide valve, horizontal	Up to 500 hp.	386 + 6.69 × hp.
	Automatic cut-off, single valve, vertical	Up to 30 hp.	164 + 9.53 × hp.
		30 to 150 hp.	372.5 + 9.55 × hp.
	Flywheel governor, Corliss non-releasing valve, horizontal	Up to 600 hp.	1100 + 8.94 × hp.
	Corliss governor and valves, horizontal	Up to 400 hp.	1040 + 8.45 × hp.
		300 to 900 hp.	730 + 9.1 × hp.
	Flywheel governor, multiple flat valves	Up to 400 hp.	685 + 7.69 × hp.
	Cross compound,		
	Ball governor, single-valve, horizontal	Up to 330 hp.	735 + 8.0 × hp.
	Ball governor, single-valve, vertical	Up to 200 hp.	750 + 10.4 × hp.
	Flywheel governor, multiported valves, horizontal	Up to 600 hp.	1100 + 9.62 × hp.
	Shaft governor, Corliss non-releasing valves, horizontal	Up to 600 hp.	2015 + 9.74 × hp.
	Tandem compound,		
	Flywheel governor and slide valves, horizontal	Up to 400 hp.	559 + 8.83 × hp.
	Flywheel governor and slide valves, vertical	Up to 140 hp.	610 + 12.7 × hp.
	Flywheel governor, Corliss non-releasing valves, horizontal	Up to 300 hp.	1295 + 10.79 × hp.
	Flywheel governor, multiple slide valves	Up to 500 hp.	1010 + 7.65 × hp.
Fans and blowers	Sizes 70 to 140 in.		6.25 × (size in inches)
Feed-water heaters	Open	Up to 1500 boiler hp.	114.5 + 0.3787 × hp.
		1500 to 3000 boiler hp.	326 + 0.237 × hp.
	Closed	Up to 3000 boiler hp.	40 + 0.72 × hp.
Generators, electric	Direct current (voltage 110-250), belted	Up to 7 kw. (1400 to 2300 r.p.m.)	21.1 + 28.5 × kw.
		10 kw. to 300 kw. (600 to 1400 r.p.m.)	10 × (kw.) — 9
	Direct-connected	Up to 300 kw. (100 to 350 r.p.m.)	313.3 + 10.93 × kw.
		300 to 1000 kw. (moderate speed)	12.08 × (kw.) − 383
	Alternating-current, belted	Up to 300 kv.a. (600 to 1800 r.p.m.)	81 + 9.723 × kv.a.
	Direct-connected	Up to 300 kv.a. (200 to 300 r.p.m.)	375 + 7.477 × kv.a.
		250 to 2500 kv.a. (100 to 250 r.p.m.)	2413 + 4.69 × kv.a.
Motors, electric	Direct-current, belted; smzll sizes	Up to 1.5 hp. (1400 to 2500 r.p.m.)	18.53 + 42.37 × hp.
		1.5 to 30 hp. (1000 to 1800 r.p.m.)	53.3 + 12.4 × hp.
		30 to 100 hp.—Upper limit (500 to 800 r.p.m.)	191.7 + 10.94 × hp.
		Lower limit—(800 to 1000 r.p.m.)	213 + 8.264 × hp.
	Variable speed	Up to 10 hp.—Upper limit	64.1 + 36.786 × hp.
		Lower limit	69.2 + 10.56 × hp.
	Alternating current:		
	Single-phase (110-220 volts)	Up to 25 hp. (1200 to 1800 r.p.m.)	25 + 11.75 × hp.
	Belted; polyphase induction	Up to 130 hp. (1200 to 1800 r.p.m.)	116 + 4.72 × hp.
	Variable speed	Up to 25 hp.	60.7 + 7.15 × hp.
		35 to 60 hp.	157.6 + 3.573 × hp.

TABLE OF COSTS OF STEAM AND GAS POWER-PLANT EQUIPMENT — Continued

Name of Apparatus	Type	Capacity	Equation of Cost in Dollars
Producers, gas	Suction	Up to 300 hp.	252 + 14.2 × hp.
	Pressure	Up to 300 hp.	860 + 15.15 × hp.
Producer plants, gas	Suction	Up to 200 hp.	570 + 46.5 × hp.
Pumps	Boiler feed		
	Single-cylinder, piston pattern	Up to 6000 gal. per hr.	17.8 + 0.2586 × (gal. per hr.)
		6000 to 27,000 gal. per hr.	106.8 + 0.011045 × (gal. per hr.)
	Duplex, piston pattern	Up to 29,000 gal. per hr.	585 + 0.0115 × (gal. per hr.)
	Single-cylinder, outside-packed, plunger pattern	Up to 24,000 gal. per hr.	0.034 × (gal. per hr.)
	Duplex, outside-packed plunger pattern	Up to 49,000 gal. per hr.	0.042125 × (gal. per hr.)
	Centrifugal		
	Horizontal, low-pressure, single-stage	Up to 14,000 gal. per min.	52 + 0.05525 × (gal. per min.)
	Horizontal, high-pressure, single-stage	Up to 5000 gal. per min.	61 + 0.0868 × (gal. per min.)
		5000 to 20,000 gal. per min.	210 + 0.0567 × (gal. per min.)
	Horizontal, high-pressure, multi-stage	Up to 2200 gal. per min.	117 + 0.233 × (gal. per min.)
	Vertical, low-pressure, single-stage	Up to 20,000 gal. per min.	60 + 0.05575 × (gal. per min.)
	Vertical, high-pressure, single-stage	Up to 20,000 gal. per min.	50 + 0.0865 × (gal. per min.)
	Vertical, high-pressure, multi-stage	Up to 1100 gal. per min.	125.7 + 0.27 × (gal. per min.)
	Geared power		
	Single cylinder	Up to 20,000 gal. per hr.	90 + 0.0316 × (gal. per hr.)
	Single-acting, triplex	Up to 83,000 gal. per hr.	56 + 0.03867 × (gal. per hr.)
	Double-acting, triplex	Up to 89,000 gal. per hr.	195 + 0.0148 × (gal. per hr.)
	Rotary force pumps	1200 to 20,000 gal. per hr.	8 + 0.0117 × (gal. per hr.)
	Wet vacuum pumps	Up to 13,000 gal. per hr.	18 + 0.01435 × (gal. per hr.)
		13,000 to 50,000 gal. per hr.	14 + 0.00863 × (gal. per hr.)
Purification plants	Water	1000 to 20,000 gal. per hr.	1000 + 0.2 × (gal. per hr.)
Stokers	Chain-grate	100 to 300 boiler hp.	86 + 4.28 × (hp.)j
		300 to 500 boiler hp.	434 + 3.1 × (hp.) f
	Front-feed	100 to 660 boiler hp.	312 + 3.015 × (hp.)
	Under-feed	Up to 600 boiler hp.	379 + 2.785 × (hp.)
Superheaters	200 to 750 boiler hp.		
		100 deg. of superheat	165 + 2.578 × (hp.)
		200 deg. of superheat	52 + 3.466 × (hp.)
		300 deg. of superheat	40 + 4.28 × (hp.)
Transformers	Air-cooled	Sizes up to 3000 kv.a	439 + 1.467 × kv.a.
	Oil-cooled	Sizes up to 30 kv.a.	
		25 cycles	52.9 + 8.1 × kv.a.
		60 cycles	26.2 + 6.25 × kv.a.
		Sizes 30 to 100 kv.a.	
		25 cycles	157 + 4.68 × kv.a.
		60 cycles	119.5 + 3.57 × kv.a.
	Water-cooled	Sizes up to 1000 kv.a.	181 + 1725 × kv.a.
		1000 to 3000 kv.a.	805 + 1099 × kv.a.
Turbines, steam	Reaction type:		
	Turbine and generator	500 to 5000 kw.	3335 + 13.33 × kw.
		5000 to 10,000 kw.	17,500 + 10.5 × kw.
	Impulse type:		
	Turbine alone	Up to 50 hp.	171.5 + 10.7 × hp.
		50 to 400 hp.	10.74 × hp. — 54
	Turbine and generator	Up to 40 kw.	304.2 + 36.78 × kw.
		25 to 350 kw.	30.4 × kw. − 100
		1000 to 10,000 kw.	8106 + 11.34 × kw.

LOAD FACTOR

$$\text{The "Load Factor"} = \frac{\text{Yearly output in K. W. hrs.}}{8760 \times \text{rated capacity in K.W.}}$$

$$\text{or} \quad \frac{\text{Yearly output in H. P. hrs.}}{8760 \times \text{rated capacity in H.P.}}$$

$$8760 = 24 \times 365.$$

$$\text{The Station Load Factor} = \frac{\text{Yearly output K. W. hrs.}}{\text{Rated capacity in K. W.} \times \text{hrs. plant ran}}$$

It is evident that the higher the load factor the cheaper the cost per K. W. hr. or per H. P. hr. becomes, inasmuch as the fixed charges are the same whether the plant is running at half load, full load, full time, half time or idle.

If a plant had to be run continuously it would be advisable to have at least one spare unit and due to the cost of this spare unit the fixed charge would be greater than for a plant which was idle at night and hence gave opportunity to make repairs, so that a spare unit was not necessary.

COST OF OPERATION

The cost of operation of a power plant may be divided into:

A. Fixed charges. 1. Investment.
2. Administration.

B. Operating expenses.

A. *Fixed Charges.*— These include under (1) interest on the investment, generally taken as 5 per cent; taxes 1 to 1.5 per cent; insurance .5 per cent; depreciation, a varying amount depending upon the life of the apparatus and maintenance or ordinary repairs, frequently taken as 2.5 per cent. The maintenance is sometimes charged against operating expense.

Under (2) such items as salaries of officers, clerks, stenographers, etc. not connected with the operating end. Office rent and office supplies are included.

B. *Operating Expenses.*— This includes coal, oil, water, supplies for boiler and turbine room and labor.

The life of the different items making up the Equipment of a Power Plant may be taken from the following table:

LIFE OF APPARATUS

	Years
Belts	7
Boilers, Fire Tubes	15
Boilers, Water Tubes	25
Breeching Steel	10
Buildings; Brick, Concrete, Steel Concrete	50
Coal Bunkers	14
Coal conveyors — rectangular, bucket	8
Coal Conveyor; Belt	10
Cranes	25
Chimneys, brick	50
Chimneys, steel, self-supporting	20
Chimneys, steel guyed	10
Economizers	20

Engines: Corliss	25
Engines: High speed	15
Feed pumps, turbine centrifugal	15
Feed pumps, plunger	12
Generators, D. C.	20
Generators, A. C.	25
Heaters, open type	20
Heaters, closed type	10
Motors	20
Motor generator sets	15
Piping	15
Steel Flues	10
Stokers	7
Switchboard	25
Turbines	15
Wiring	20

DEPRECIATION

If the life of a piece of apparatus is known to be 20 years, that is to say, at the end of 20 years the apparatus is considered worthless and its value as junk is enough to pay for its removal, then each year a certain amount of money should be put by as a sinking fund so that at the end of the 20th year, this money shall have accumulated to a sum sufficient to replace the apparatus.

Evidently if the money put away did not draw interest, 5 per cent of the original cost would be added to the sinking fund each year; if however, the money drew 4½ per cent interest, compounded annually, the amount to be laid by each year would be 3.19 per cent of the first cost of the apparatus as is found by reference to the "interest table" which follows:

This table has been calculated by means of the formula $X = \dfrac{100R}{(1+R)^n - 1}$

X = rate of depreciation expressed in per cent of first cost.
R = rate of interest received, compounded annually; expressed as a decimal.
n = years of life of apparatus.
S = first cost of apparatus.

This formula may be deduced thus:

The amount of money laid by each year is $\dfrac{X}{100}S$

There has accumulated then

at the end of the first year $\dfrac{X}{100}S$

at the end of the second year $\dfrac{X}{100}S\,(1+R) + \dfrac{X}{100}S$

at the end of the third year $\dfrac{X}{100}S\,(1+R)^2 + \dfrac{X}{100}S\,(1+R) + \dfrac{X}{100}S$

at the end of the fourth year $\dfrac{X}{100}S\,(1+R)^3 + \dfrac{X}{100}S\,(1+R)^2 + \dfrac{X}{100}S\,(1+R) + \dfrac{X}{100}S$

at the end of the *nth* year $\frac{X}{100}S\,(1+R)^{n-1} \ldots \frac{X}{100}S\,(1+R)^2 + \frac{X}{100}S\,(1+R) + \frac{X}{100}S$

This summation should equal S.

Equating and solving for X.

$$X = \frac{100}{(1+R)^{n-1} + \ldots (1+R)^2 + (1+R) + 1}$$

The summation of a series $X^{n-1} \ldots X^2 + X + 1 = \frac{X^n - 1}{X - 1}$

$$\text{hence } X = \frac{100\,(1+R) - 1}{(1+R)^n - 1} = \frac{100R}{(1+R)^n - 1}$$

RATE OF DEPRECIATION

(Per Cent of First Cost)

Rate of Interest, Per Cent.

	3	3.5	4	4.5	5	5.5	6	7	8
5	18.83	18.65	18.46	18.28	18.10	17.91	17.73	17.40	17.04
6	15.46	15.26	15.08	14.89	14.70	14.52	14.33	13.97	13.63
7	13.05	12.85	12.66	12.46	12.28	12.09	11.91	11.15	11.20
8	11.24	11.05	10.85	10.66	10.47	10.28	10.10	9.74	9.40
9	9.84	9.64	9.45	9.26	9.07	8.88	8.70	8.34	8.00
10	8.72	8.52	8.33	8.14	7.95	7.76	7.58	7.23	6.90
11	7.80	7.61	7.41	7.22	7.04	6.85	6.68	6.33	6.00
12	7.04	6.85	6.65	6.46	6.28	6.10	5.92	5.60	5.27
13	6.40	6.20	6.01	5.83	5.64	5.47	5.29	4.96	4.65
14	5.85	5.65	5.46	5.28	5.10	4.93	4.75	4.49	4.13
15	5.37	5.18	4.99	4.81	4.63	4.46	4.29	3.97	3.66
16	4.96	4.77	4.58	4.40	4.22	4.06	3.89	3.58	3.30
17	4.59	4.40	4.22	4.04	3.87	3.70	3.54	3.24	2.96
18	4.27	4.08	3.90	3.72	3.55	3.39	3.23	2.94	2.66
19	3.98	3.79	3.61	3.44	3.27	3.11	2.96	2.67	2.47
20	3.72	3.53	3.36	3.19	3.02	2.87	2.71	2.44	2.18
25	2.74	2.56	2.40	2.24	2.09	1.95	1.82	1.58	1.36
30	2.10	1.93	1.78	1.64	1.50	1.38	1.26	1.06	0.88
35	1.65	1.50	1.36	1.23	1.10	0.99	0.89	0.72	0.58
40	1.32	1.18	1.05	0.93	0.83	0.73	0.64	0.50	0.38
45	1.07	0.94	0.82	0.72	0.62	0.54	0.47	0.35	0.26
50	0.88	0.76	0.65	0.56	0.42	0.40	0.34	0.25	0.17

Assumed useful life of apparatus at left of column.

The continuous expense based upon the original cost of the plant is sometimes taken as 14 per cent per year divided as follows: interest 5 per cent; depreciation 5 per cent, repairs 2½ per cent, insurance ½ per cent and taxes 1 per cent.

OPERATING COSTS IN CENTS PER K. W. HOUR FOR CERTAIN CENTRAL STATIONS IN MASSACHUSETTS

Coal	.462	.710	.618	.690	.703	.565	.635	.880	.740	.650	.740
Wages	.192	.262	.296	.347	.360	.320	.342	.538	.308	.285	.410
Oil, Waste, etc.	.008	.009	.012	.019	.027	.020	.017	.032	.015	.019	.025
Water	.024	.008	.040	.055	.034	.045	.032	.012	.025	.003	.027
Station Repairs, Bldgs.	.015	.020	.052	.021	.012	.023	.035	.012	.017	.063	.034
Steam Equipment Repairs	.042	.020	.147	.059	.055	.072	.072	.037	.041	.073	.158
Electrical Equipment Repairs	.056	.009	.045	.046	.055	.014	.014	.029	.072	.019	.011
Miscellaneous	.023	.022	.000	.000	.000	.021	.033	.080	.024	.040	.000
Total	.822	1.060	1.210	1.237	1.246	1.080	1.180	1.620	1.242	1.152	1.412
Coal per ton $	3.99	4.75	3.60	4.40	4.79	3.78	4.49	4.68	4.52	3.97	4.51
Output K. W. Hours / 1,000,000	88.5	9.4	8.7	6.0	5.4	4.7	4.6	4.0	4.0	3.7	3.1

BOSTON ELEVATED RAILWAY COMPANY

Year	1906	1908	1910	1912
Rated capacity	38,470	50,425	51,163	61,350
Yearly load factor	43	37	41.5	36.4
Cost of coal per K. W. hour, cents	.47	.56	.48	.41
Labor plus labor on repairs per K. W. hour, cents	.17	.21	.17	.17
Coal and all supplies per K. W. hour, cents	.60	.86	.58	.52
Total per K. W. hour, cents	.77	1.07	.75	.69
Cost of coal per ton $	3.186	3.568	3.283	3.202

OPERATING COSTS, COSTS IN CENTS PER K. W. HOUR

Typical British Electric Light and Power Plants — 1902
(From Engineering Record — March, 1904)

K. W. installed	Yearly load factor per cent	Coal	Oil, waste and Supplies	Wages	Repairs	Total
6380	20.93	.52	.10	.16	.26	1.04
8740	12.31	.56	.06	.34	.28	1.24
1340	17.84	.52	.06	.34	.38	1.30
10477	14.75	.68	.08	.18	.36	1.30
3700	18.87	.70	.12	.30	.20	1.32
850	28.44	.82	.06	.30	.22	1.40
21190	25.11	.74	.12	.30	.26	1.42
1600	15.82	.74	.08	.40	.30	1.52
5642	12.97	.92	.20	.32	.18	1.62
1920	13.31	.72	.12	.36	.46	1.66
610	14.54	.92	.20	.36	.22	1.70
990	19.79	1.10	.08	.42	.18	1.78

TOTAL COST IN DOLLARS OF A H. P. FOR A YEAR ON 10 HOUR BASIS

Size of Plant H. P.	Maximum Cost per H. P.	Minimum Cost per H. P.
2000	24	21
1500	26	21
1200	30	22
1000	33	24
800	38	26
600	46	28
500	50	31
400	57	33
300	65	38
200	77	45
100	96	60
50	110	80
25	130	110

DISTRIBUTION OF OPERATING COSTS

The operating cost per K. W. hour varies from less than one cent in the large plants to three and one-half cents in the small plants. Plants of from 2000 to 5000 K. W. capacity would operate between one and one-half and one and one-tenth cents.

The cost is distributed about as follows:

	Per Cent
Coal	56.0
Wages	28.0
Oil and waste, etc.	2.0
Water	2.0
Station Repairs, Bldgs.	1.6
Steam Equipment Repairs	6.3
Electrical Equipment Repairs	4.1
	100.0

A certain station of 10,000 K. W. rated capacity cost $100 per K. W. This cost was divided as follows: Buildings $20, Machinery $80. Charging 14 per cent on machinery and 7.5 per cent on buildings gives for fixed charges,

$$.075 \times 200{,}000 = 15{,}000$$
$$.14 \times 800{,}000 = 112{,}000$$
$$127{,}000$$

Suppose the yearly load factor is 18 per cent and that the total operating cost per K. W. hour, is 1.121 cents.

The total output in K. W. hours for the year is

$$8760 \times 10{,}000 \times .18 = 15{,}768{,}000$$
$$\$127000 \div 15{,}768{,}000$$

gives the overhead charge per K. W. hour to be added to the operating cost. This figures as .804 cents.

$$.804 + 1.12 = 1.925 \text{ cents.}$$

It is evident that the higher the load factor the less the overhead to be added per K. W. to operating cost.

COST OF STEAM POWER — (Small Units)

Size of plant in H. P.	6	10	20
Cost of plant per H. P.	$250.00	$220.00	$200.00
Fixed charge, 14 per cent	$35.00	$30.80	$28.00
Coal per H. P. hour, in pounds	20	15	12
Cost of coal at $5 per ton	$154.00	$103.00	$82.50
Attendance, 3080 hours	75.00	50.00	30.00
Oil, waste and supplies	15.00	10.00	6.00
Cost 1 H. P. per annum, 10-hour basis	$279.00	$194.80	$146.50
Cost of 1 H. P. per hour	$0.0906	$0.0832	$0.0475

COST OF GASOLENE POWER — Small Units

Engineering News, Aug. 15, 1907.

Size of plant in H. P.	2	6	10	20
Price of engine in place	$150.00	$325.00	$500.00	$750.00
Gasolene per B. H. P. per hour	⅓ gal.	¼ gal.	⅙ gal.	⅛ gal.
Cost per gallon	$0.22	$0.20	$0.19	$0.18
Cost per 3,080 hours	$451.53	$924.00	$975.13	$1386.00
Attendance at $1 per day	308.00	308.00	308.00	308.00
Interest, 5 per cent	7.50	16.25	25.00	37.50
Depreciation, 5 per cent	7.50	16.25	25.00	37.50
Repairs, 10 per cent	15.00	32.50	50.00	75.00
Supplies, 20 per cent	30.00	65.00	100.00	150.00
Insurance, 2 per cent	3.00	6.50	10.00	15.00
Taxes, 1 per cent	1.50	3.25	5.00	7.50
Power Cost	$825.03	$1371.75	$1498.13	$2016.50

To these figures should be added charges on space occupied as follows:

Value of space occupied	$100.00	$150.00	$200.00	$300.00
Interest, 5 per cent	$5.00	$7.50	$10.00	$15.00
Repairs, 2 per cent	2.00	3.00	4.00	6.00
Insurance, 1 per cent	1.00	1.50	2.00	3.00
Taxes, 1 per cent	1.00	1.50	2.00	3.00
Total annual charge for space	$9.00	$13.50	$18.00	$27.00
Total cost per annum	$833.03	$1385.25	$1516.13	$2043.30
Cost of 1 H. P. per annum, 10 hour basis	416.51	239.87	151.61	102.17
Cost of 1 H. P. per hour	$0.1352	$0.0780	$0.0492	$0.0331

COST OF GAS POWER — Small Units

$1.50 per 1000 cubic feet of gas less 20 per cent, if paid in 10 days = $1.20 net, gas 760 B. T. U.

Size of plant in H. P.	2	6	10	20
Engine cost in place	$200.00	$375.00	$550.00	$1050.00
Gas per H. P. hour in cu. ft.	30	25	22	20
Value of gas consumed, 3080 hours	$221.76	$554.40	$843.12	$1478.00
Attendance, $1 per day	308.00	308.00	308.00	308.00
Interest, 5 per cent	10.00	18.75	27.50	52.50
Depreciation, 5 per cent	10.00	18.75	27.50	52.50
Repairs, 10 per cent	30.00	37.50	55.00	105.00
Supplies, 20 per cent	40.00	75.00	110.00	210.00
Insurance, 2 per cent	4.00	7.50	11.00	21.00
Taxes, 1 per cent	2.00	3.75	5.50	10.50
Power cost	$615.76	$1023.65	$1387.62	$2237.50
Annual charge for space	9.00	13.50	18.00	27.00
Total cost per annum	$624.76	$1037.15	$1405.62	$2264.50
Cost of 1 H. P. per annum, 10 hour basis	312.38	172.86	110.56	143.22
Cost of 1 H.P. per hour	$0.1014	$0.0561	$0.0456	$0.0367

GUARANTEES

It is customary to ask that contractors, when submitting a bid for prime movers or for power-driven machinery, give a guarantee as to the performance or efficiency of the equipment they propose to furnish.

This guarantee may in the case of a steam engine be based on pounds of steam per I. H. P. or per K. W. hour at rated load which should be specified, as should also the pressure and condition of the steam at the throttle and the temperature of the cold condensing water.

The steam consumption at half load and at twenty-five per cent overload may also be given and included in the guarantee.

The performance of large pumping engines is stated in figures representing the "duty" or foot pounds of water work done per 1,000,000 B. T. U. or per 1000 lbs. of steam of quality and pressure specified.

The performance of centrifugal pumping units when motor driven is often given in overall mechanical efficiency of pump and motor when working at stated conditions as to head and capacity.

In contracts containing a guarantee as to performance, provision is made for deducting from the first cost of the apparatus a fixed amount for each fraction of a pound the engine or turbine exceeds the consumption mentioned in the guarantee; similarly in the case of a high duty pumping engine a deduction is made for each million duty under that guaranteed.

It is not necessary that there be a "bonus" for a performance better than that guaranteed.

The deduction made from the original price in case of a failure to meet the guarantee is in no way to be in the nature of a penalty. It must be that amount which the purchaser would lose in money and accrued interest during the life of the apparatus through the less efficient performance than that guaranteed.

For example, a certain contractor guaranteed a steam consumption per I. H. P. hour on an engine and condenser and failed to meet his guarantee.

The contract read that should the steam consumption per I. H. P. at full load, namely 2000 I. H. P., exceed 13.7 lbs. per I. H. P. hour a deduction is to be made from the original contract price at the rate of $4400 per 1/10 lb. that the actual performance exceeds the guaranteed steam consumption, provided the steam consumption does not exceed that guaranteed by as much as 3/10 of a pound. Should the steam consumption at full load exceed that guaranteed by 3/10 of a pound or more, the purchaser could at his option reject the engine.

The figure $4400 was arrived at in this way:

The life of the engine may be taken as 18 years and it may be assumed to run 3000 hours per year with full load in this case. The extra steam per hour per 1/10 lb. in excess of guarantee is per year $.1 \times 2000 \times 3000 = 600{,}000$ lbs. for engine alone. Adding 10% of this as the extra steam used by the auxiliaries makes 660,000 lbs. Assuming 9.5 lbs. actual evaporation per lb. of coal makes the extra coal per year 69,474 lbs. or 34.74 tons. With coal at $4.50 per ton this figures $156.33.

If money draws 5 per cent interest, the loss at the end of 18 years may be figured as follows:

End of first year,	156.33
End of second year,	$1.05 \times 156.33 + 156.33$
End of third year,	$1.05^2 \times 156.33 + 1.05 \times 156.33 + 156.33$
End of fourth year,	$1.05^3 \times 156.33 + 1.05^2 \times 156.33 + 1.05 \times 156.33 + 156.33$
End of 18th year,	$1.05^{17} \times 156.33 + 1.05^{16} \times 156.33 + \ldots . 1.05 \times 156.33 + 156.33$
	$= \$4402.25$

If R is taken as the rate of interest; n = number of years and the loss for the first year is $1. This may be written:

$$1 + (1+R) + (1+R)^2 + (1+R)^3 + \ldots\ldots (1+R)^{n-1} = \frac{1-(1+R)^n}{1-(1+R)},$$

which may be put into this form

$$\frac{(1+R)^n - 1}{R}$$

One dollar lost each year plus the interest which would have accrued would at the end of n years amount to $\frac{(1+R)^n - 1}{R}$ which is the "annuity value of one dollar."

In the case just considered this gives

$$\frac{(1+.05)^{18} - 1}{.05} = 28.16 \qquad 28.16 \times 156.33 = \$4402.25$$

A guarantee on the duty of a 12,000,000 gallon pump read as follows: "With steam at the throttle of 150 lbs. gage pressure and containing not over 1½ per cent moisture, the pump is guaranteed when pumping 12,000,000 U. S. gallons in 24 hours against a total head of 200 feet to give a duty of 140,000,000 per 1000 lbs. of steam."

"Should the pump fail to make the duty guaranteed an amount representing the monetary loss suffered by the city in a period of 20 years, taken as the life of the pump, is to be deducted from the original contract price of the pump."

"The amount to be deducted per 1,000,000 loss of duty as calculated and mutually agreed upon by engineers representing the city and the contractor is $2116.41."

"The extra cost of coal per year per million loss of duty, figured on coal at $4.60 a ton with an evaporation of 10 lbs. of water per pound of coal and on the basis that the pump runs only 90 per cent of the year and that it runs at 5/6 of its rated capacity is $63.94."

The annuity value of $1 for 20 years at 5 per cent is $33.1.

$$63.94 \times 33.1 = \$2116.41.$$

The calculations are outlined below:

$$365. \times .9 = 328.5 \text{ days}$$

12,000,000 × 5/6 = 10,000,000 gals. per 24 hours.

328.5 × 10,000,000 × 8.33 × 200 = ft. lbs. per year.

$$\frac{\text{Ft. lbs. per year}}{140{,}000{,}000} = \frac{\text{steam used per year}}{1000} = 39{,}092 \text{ (A)}$$

$$\frac{\text{Ft. lbs. per year}}{139{,}000{,}000} = \frac{\text{steam used per year}}{1000} = 39370 \text{ (B)}$$

	Steam per year	Coal per year, lbs.	Coal per year, tons
B	39,370,000	3,937,000	1968.5
A	39,092,000	3,909,200	1954.6
			13.9

13.9 × 4.60 = $63.94
63.94 × 33.1 = $2116.41

PIPING

Steel pipe is cheaper than wrought iron pipe and is generally furnished when an order is given for pipe unless *wrought iron* pipe is specifically called for.

There are two weights of pipe in addition to the *Extra Strong* and *Double Extra Strong* one known as "Merchant," and the other known as "Card" or "Full Weight" pipe.

The term "Standard" or "Merchant," is used to describe a pipe not "Card" or "Full Weight."

For many purposes this lighter weight is just as good as the "Full Weight."

The term "Card" or "Full Weight" refers to a pipe of weights as given in the table which follows.

Pipe in sizes up to and including 12″ refers to inside dia. Above 12″ the pipe is rated by the outside dia.

Pipe comes in lengths of from 18 ft. to 21 ft. and in figuring the cost of a system of piping there is some waste pipe which must be taken account of.

Pages 141 to 154 are taken from the catalogue of the Walworth Mfg. Co. The discounts vary from time to time but may be assumed as being approximately correct.

The coefficient of expansion of steel piping is .0000065 or in other words, a pipe expands .0000065 its length per degree F.

The expansion on high pressure work is taken care of by expansion bends similar to those shown on the plot (page 155).

The amount of motion such bends will provide for has been determined experimentally by the Crane Company. The results of this work were published in the Valve World of October, 1915. This plot is reproduced from that paper.

If the total expansion to be taken up by a double offset or U bend is 5″ in general, the bend or offset would be sprung apart one-half the expansion, or in this case 2½″ when the pipe was erected. By this means the expansion first relieves the stress, then puts into the pipe a stress of the opposite kind but of equal amount.

Much of the high pressure piping put up to-day has outlets, taking the place of cast tees, welded to the pipe. This saves joints and thereby reduces the trouble from leaky gaskets.

The labor cost of the erection of piping depends upon the design of the system; in general however, for the ordinary power house the cost varies from 15 per cent to 25 per cent of the first cost of the fabricated material; 15 per cent would be considered a low cost; 20 per cent about an average value.

Card or Full Weight pipe is generally used for pressures carried in power plants.

The discount on card or Full Weight is 68 per cent. The discount on Extra Strong 62 per cent; on Double Extra Strong 45 per cent.

PRICE LIST OF
WROUGHT IRON AND STEEL PIPE.

Nominal Inside Diameter.	STANDARD.		EXTRA STRONG.		DOUBLE EXTRA STRONG.	
	Price Per Foot.	Nominal Weight Per Foot.	Price Per Foot.	Nominal Weight Per Foot.	Price Per Foot.	Nominal Weight Per Foot.
⅛	.05½	0.24	.11	0.29	------	------
¼	.05½	0.42	11	0.54	------	------
⅜	.05½	0.56	11	0.74	.25	.96
½	.08½	0.85	.12	1.09	.25	1.70
¾	.11½	1.12	15	1.39	.30	2.44
1	.16½	1.67	.22	2.17	.37	3.65
1¼	.22½	2.24	.30	3.00	.52	5.20
1½	.27	2.68	.36	3.63	65	6.40
2	.36	3.61	.50	5.02	95	9.02
2½	.57½	5.74	.81	7.67	1.37	13.68
3	.75½	7.54	1.05	10.25	1.92	18.56
3½	.95	9.00	1.33	12.47	2.45	22.75
4	1.08	10.66	1.50	14.97	2.85	27.48
4½	1.30	12.49	1.95	18.22	3.30	32.53
5	1.45	14.50	2.16	20.54	3.80	38.12
6	1.88	18.76	2.90	28.58	5.30	53.11
7	2.35	23.27	3.80	37.67	6.25	62.38
8	2.50	25.00	------	------	------	------
8	2.82	28.18	4.30	43.00	7.20	71.62
9	3.40	33.70	5.00	48.73	------	------
10	3.50	35.00	------	------	------	------
10	4.00	40.00	5.50	54.74	------	------
12	4.50	45.00	6.50	65.42	------	------
12	4.90	49.00	------	------	------	------

On orders for 8-inch, 10-inch, 12-inch pipe we will ship 8-inch, 25 lb., 10-inch, 35 lb., 12-inch, 45 lb., unless otherwise specified. Customers should, however, always indicate which weight is wanted.

When Standard Pipe is ordered, black pipe, random lengths, with threads and couplings, will be shipped, unless otherwise specified.

For pipe smoothed on the inside, known as plugged and reamed, an extra charge will be made above regular pipe.

Extra Strong and Double Extra Strong Pipe will be shipped in random lengths and plain ends, unless otherwise ordered. For this pipe, fitted with threads and couplings, an extra charge will be made above regular. For cut lengths of any pipe, an extra charge will be made above random lengths. For galvanized or asphalted pipe, an extra charge will be made above black.

For Price List for Cutting and Threading, see page 79.

GALVANIZED FLANGED FITTINGS.

Faced and Drilled.

Size. Inches.	90° Elbows. Galvanized	45° Elbows. Galvanized.	Tees. Galvanized.	Reducing Tees. Galvanized.	Crosses. Galvanized.	Y-Branches. Galvanized.
3	2.80	2.35	4.40	4.75	5.85	----
4	4.00	3.70	6.40	7.00	9.70	9.90
5	5.50	4.90	8.00	8.80	12.00	12.60
6	6.40	5.50	9.20	9.80	13.50	16.50
7	8.00	6.00	11.20	12.00	19.00	18.70
8	12.30	9.50	18.00	19.00	31.00	27.00
9	17.00	14.00	22.50	24.00	40.00	37.50
10	19.20	15.00	26.00	28.00	50.00	50.00
12	26.60	22.00	41.00	44.00	72.00	71.00
14	41.70	24.00	61.00	66.00	86.00	100.00
15	53.00	30.00	76.00	82.00	108.00	116.00
16	76.00	49.00	113.50	122.00	138.00	168.00
18	91.00	70.00	148.00	159.00	174.00	191.00
20	120.00	84.00	157.00	168.00	197.00	208.00
22	142.00	100.00	206.00	222.00	260.00	266.00
24	178.00	122.00	253.00	272.00	325.00	336.00

The above list is for fittings drilled in accordance with SPIRAL PIPE STANDARD.

These fittings are also furnished flanged and drilled in accordance with A. S. M. E., Standard at an additional cost.

Base elbows for supporting vertical runs furnished as ordered.

SPIRAL RIVETED GALVANIZED PRESSURE PIPE.

Lengths up to 20 Feet.

Size. Inches.	U. S. Standard Gauge.	Per Foot. Galvanized. No Flanges.	*Flanges Attached. Each.	**Diameter Flanges. Inches.	Bolt Circle. Inches.	No. of Bolts.	Size Bolts. Inches.
3	20	.474	1.90	6	4¾	4	7/16
4	18	.680	2.30	7	5 15/16	8	7/16
5	18	.826	2.70	8	6 15/16	8	7/16
6	16	1.04	3.15	9	7⅞	8	½
7	16	1.216	3.40	10	9	8	½
8	16	1.395	4.05	11	10	8	½
9	16	1.564	4.90	13	11¼	8	½
10	16	1.731	5.45	14	12¼	8	½
12	16	2.067	5.85	16	14¼	12	½
14	14	2.91	6.80	18	16¼	12	½
15	14	3.12	9.35	19	17 7/16	12	½
16	14	3.33	11.00	21¼	19¼	12	½
18	14	3.66	13.35	23¼	21¼	16	⅝
20	14	4.06	15.85	25¼	23⅛	16	⅝
22	12	5.91	20.25	28¼	26	16	⅝
24	12	6.41	22.70	30	27¾	16	⅝

*Flanges Drilled.

**Spiral Pipe Diameters. Additional price charged for A. S. M. E. Standard Diameters.

The discount on Spiral Riveted pipe is 40 per cent. Galvanized fittings cost 15 per cent. more than the net price of ordinary cast iron or flanged fittings.

TABLE OF DIMENSIONS OF *CARD OR FULL WEIGHT WROUGHT IRON OR STEEL PIPE.

For Steam, Water and Gas.

Nominal Inside Diam. Ins.	Actual Outside Diameter. Inches.	Approx. Inside Diameter. Inches.	Approx. Thickness. Inches.	Length of Pipe per Sq. Ft. of Outside Surface. Feet.	Inside Area. Inches.	Length of Pipe Containing One Cu. Ft. Feet.	**Nominal Weight per Ft. Pounds.	No. of Threads per Inch of Screw.	Contents in ***Gals. per Ft.
⅛	.405	.270	.068	9.44	.0568	2513.	.24	27	.0006
¼	.54	.364	.088	7.075	.1041	1383.3	.42	18	.0026
⅜	.675	.494	.091	5.657	.1909	751.5	.56	18	.0057
½	.84	.623	.109	4.547	.3039	472.4	.85	14	.0102
¾	1.05	.824	.113	3.637	.5333	270.	1.12	14	.0230
1	1.315	1.048	.134	2.903	.8609	166.9	1.67	11½	.0408
1¼	1.66	1.380	.140	2.301	1.496	96.25	2.24	11½	.0638
1½	1.90	1.611	.145	2.010	2.038	70.65	2.68	11½	.0918
2	2.375	2.067	.154	1.608	3.355	42.91	3.61	11½	.1632
2½	2.875	2.468	.204	1.328	4.780	30.11	5.74	8	.2550
3	3.50	3.067	.217	1.091	7.388	19.49	7.54	8	.3673
3½	4.00	3.548	.226	.955	9.887	14.56	9.00	8	.4998
4	4.50	4.026	.237	.849	12.730	11.31	10.66	8	.6528
4½	5.00	4.508	.246	.765	15.961	9.03	12.49	8	.8263
5	5.563	5.045	.259	.687	19.985	7.20	14.50	8	1.020
6	6.625	6.065	.280	.577	28.886	4.98	18.76	8	1.469
7	7.625	7.023	.301	.501	38.743	3.72	23.27	8	1.999
8	8.625	7.982	.322	.444	50.021	2.88	28.18	8	2.611
9	9.625	8.937	.344	.397	62.722	2.29	33.70	8	3.300
10	10.75	10.019	.366	.355	78.822	1.82	40.00	8	4.081
12	12.75	12.000	.375	.299	113.098	1.270	49.00	8	5.87

"MERCHANT WEIGHT" WROUGHT IRON OR STEEL PIPE.

8-INCH, 10-INCH, 12-INCH SIZES.

Nominal Inside Diam. Ins.	Actual Outside Diameter. Inches.	Approx. Inside Diameter. Inches.	Approx. Thickness. Inches.	Length of Pipe per Sq. Ft. of Outside Surface. Feet.	Inside Area. Inches.	Length of Pipe Containing One Cu. Ft. Feet.	**Nominal Weight per Ft. Pounds.	No. of Threads per Inch of Screw.	Contents in ***Gals. per Ft.
8	8.625	8.073	.276	.444	51.187	2.81	25.00	8	2.659
10	10.750	10.138	.306	.355	80.715	1.78	35.00	8	4.190
12	12.750	12.094	.328	.299	114.875	1.25	45.00	8	5.967

*EXTRA STRONG WROUGHT IRON OR STEEL PIPE.

Nominal Inside Diam. Inches.	Approx. Inside Diameter. Inches.	Actual Outside Diameter. Inches.	Approx. Thickness. Inches.	Length of Pipe per Square Foot of Outside Surface. Feet.	Inside Area. Square Inches.	**Nominal Weight per Foot. Pounds.
⅛	.205	.405	.10	9.433	.033	.29
¼	.294	.54	.123	7.075	.068	.54
⅜	.421	.675	.127	5.657	.139	.74
½	.542	.84	.149	4.547	.231	1.09
¾	.736	1.05	.157	3.637	.425	1.39
1	.951	1.315	.182	2.904	.710	2.17
1¼	1.272	1.66	.194	2.301	1.271	3.00
1½	1.494	1.90	.203	2.010	1.753	3.63
2	1.933	2.375	.221	1.608	2.935	5.02
2½	2.315	2.875	.280	1.328	4.209	7.67
3	2.892	3.50	.304	1.091	6.569	10.25
3½	3.358	4.00	.321	.955	8.856	12.47
4	3.818	4.50	.341	.849	11.449	14.97
4½	4.280	5.00	.360	.764	14.387	18.22
5	4.813	5.563	.375	.687	18.193	20.54
6	5.751	6.625	.437	.577	25.976	28.58
7	6.625	7.625	.500	.501	34.472	37.67
8	7.625	8.625	.500	.443	45.664	43.00
9	8.62	9.62	.500	.397	58.426	48.25
10	9.75	10.75	.500	.355	74.662	54.00
12	11.75	12.75	.500	.299	108.430	65.00

*DOUBLE EXTRA STRONG WROUGHT IRON OR STEEL PIPE.

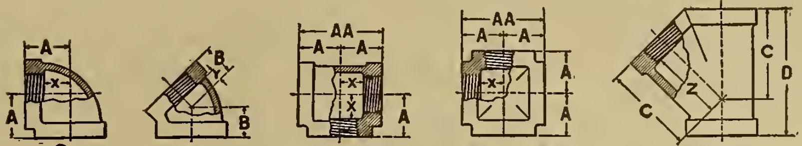
Nominal Inside Diam. Inches.	Approx. Inside Diameter. Inches.	Actual Outside Diameter. Inches.	Approx. Thickness. Inches.	Length of Pipe per Square Foot of Outside Surface. Feet.	Inside Area. Square Inches.	**Nominal Weight per Foot. Pounds.
⅜	.230	.675	.220	5.660	.041	.96
½	.244	.84	.298	4.547	.047	1.70
¾	.422	1.05	.314	3.637	.140	2.44
1	.587	1.315	.364	2.904	.271	3.65
1¼	.885	1.66	.388	2.304	.615	5.20
1½	1.088	1.90	.406	2.010	.930	6.40
2	1.491	2.375	.442	1.608	1.744	9.02
2½	1.755	2.875	.560	1.328	2.419	13.68
3	2.284	3.50	.608	1.091	4.097	18.56
3½	2.716	4.00	.642	.955	5.794	22.75
4	3.136	4.50	.682	.849	7.724	27.48
4½	3.564	5.00	.718	.764	9.976	32.53
5	4.063	5.563	.75	.687	12.965	38.12
6	4.875	6.625	.875	.577	18.665	53.11
7	5.875	7.625	.875	.501	27.109	62.38
8	6.875	8.625	.875	.443	37.122	71.62

DIMENSIONS OF

STANDARD WEIGHT

CAST IRON SCREWED FITTINGS.

For Steam Working Pressures up to 125 Lbs.



11 12 13 21 31 32 51 52 71

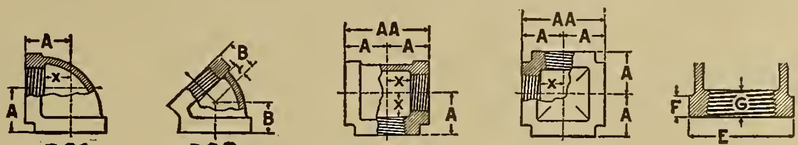
Size .... Inches	1/4	3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	3 1/2	4	4 1/2	5	6	7	8	9	10	12
A-Center to Face..Inches	3/4	7/8	1 1/16	1 5/16	1 1/2	1 13/16	2	2 3/8	2 7/8	3 5/16	3 11/16	4	4 7/16	4 11/16	5 5/16	6 1/16	6 13/16	7 1/2	8 1/4	9 9/16
AA-Face to Face..Inches	1 1/2	1 3/4	2 1/8	2 5/8	3	3 5/8	4	4 3/4	5 3/4	6 5/8	7 3/8	8	8 7/8	9 3/8	10 5/8	12 1/8	13 5/8	15	16 1/2	19 1/8
B-Center to Face..Inches	7/16	9/16	11/16	13/16	15/16	1 1/16	1 3/16	1 3/8	1 5/8	1 7/8	2 1/16	2 1/4	2 7/16	2 9/16	2 13/16	3 1/8	3 9/16	3 7/8	4 5/16	4 7/8
C-Center to Face..Inches	---	1 7/16	1 7/8	2 1/16	2 1/2	3	3 1/4	4	5	5 5/8	6 3/8	7 1/8	7 7/8	8 1/2	9 15/16	11 1/4	12 15/16	14 1/2	16	---
D-Face to Face...Inches	---	2 1/16	2 9/16	2 3/4	3 1/4	3 3/4	4 3/4	5 1/2	6 13/16	7 5/8	8 3/4	9 3/4	10 1/2	11 5/16	13 1/8	14 5/8	16 13/16	19	20 7/8	---
X-Center to Back of Thread.. Inches	3/8	7/16	9/16	3/4	7/8	1 1/8	1 3/16	1 1/2	1 7/8	2 5/16	2 5/8	2 7/8	3 3/16	3 7/16	3 15/16	4 9/16	5 3/16	5 3/4	6 1/2	7 11/16
Y-Center to Back of Thread.. Inches	1/16	1/8	3/16	1/4	5/16	3/8	3/8	1/2	5/8	7/8	1	1 1/8	1 3/16	1 5/16	1 7/16	1 5/8	1 15/16	2 1/8	2 9/16	3
Z-Center to Back of Thread.. Inches	---	1	1 3/8	1 1/2	1 7/8	2 5/16	2 7/16	3 1/8	4	4 5/8	5 5/16	6	6 5/8	7 1/4	8 9/16	9 3/4	11 5/8	12 3/4	14 1/4	---

DIMENSIONS OF

EXTRA HEAVY

CAST IRON SCREW FITTINGS.

For Steam Working Pressures to 250 Lbs.



331 332 333 334.

Size .... Inches	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	3 1/2	4	4 1/2	5	6	---
A-Center to Face .... Inches	1 5/32	1 3/8	1 19/32	1 15/16	2 1/16	2 1/2	3	3 11/16	4 1/32	4 15/32	4 27/32	5 7/32	5 13/16	---
AA-Face to Face .... Inches	2 5/16	2 3/4	3 3/16	3 7/8	4 1/8	5	6	7 3/8	8 1/16	8 15/16	9 11/16	10 7/16	11 5/8	---
B-Center to Face .... Inches	3/4	7/8	1	1 3/16	1 1/4	1 1/2	1 3/4	2 1/4	2 7/16	2 11/16	2 7/8	3 1/8	3 5/16	---
E-Outside Diameter of Bead..Inches	1 21/32	1 29/32	2 5/16	2 3/4	3 1/16	3 3/4	4 9/16	5 3/8	6	6 13/16	7 3/8	7 15/16	9 5/16	---
F-Width of Bead .... Inches	7/16	1/2	9/16	11/16	3/4	7/8	1	1 1/4	1 5/16	1 7/16	1 9/16	1 11/16	1 3/4	---
G-Thread Length .... Inches	9/16	5/8	11/16	13/16	7/8	1	1 1/8	1 3/8	1 7/16	1 9/16	1 11/16	1 13/16	1 7/8	---
X-Center to Back of Thread..Inches	19/32	3/4	29/32	1 1/8	1 5/16	1 5/8	2	2 5/16	2 1/16	2 7/16	2 13/16	3 3/16	3 15/16	---
Y-Center to Back of Thread..Inches	3/16	1/4	5/16	3/8	3/8	1/2	5/8	7/8	1	1 1/8	1 3/16	1 5/16	1 7/16	---

STANDARD WEIGHT.

CAST IRON SCREWED FITTINGS.

125 Lbs. Working Pressure.

STRAIGHT ELBOWS.

Size Inches	¼	⅜	½	¾	1	1¼	1½	2	2½	3
Fig. 11, R. H. Each	.05	.05	.06	.08	.10½	.16	.20	.28	.50	.75
R. H. Galvanized Each	.10	.10	.12	.16	.21	.32	.40	.56	1.00	1.50
Fig. 12, R. and L. Each	.06	.06	.07	.09	.12	.18	.23	.32	.60	.85
Size Inches	3½	4	4½	5	6	7	8	9	10	12
Fig. 11, R. H. Each	1.05	1.20	1.75	2.00	2.75	4.70	6.75	9.00	13.50	20.00
R. H. Galvanized Each	2.10	2.40	3.50	4.00	5.50	9.40	13.50	18.00	27.00	40.00

For Elbows tapped left hand use Right and Left Elbow List.
Right and Left Hand Elbows have ribs on the band of the end that is tapped left hand.

REDUCING ELBOWS.

Size Inches	⅜	½	¾	1	1¼	1½	2	2½	3	3½
Fig. 13 Each	.06	.07	.09	.12	.18	.23	.32	.60	.85	1.20
Galvanized Each	.12	.14	.18	.24	.36	.46	.64	1.20	1.70	2.40
Size Inches	4	4½	5	6	7	8	9	10	12	----
Fig. 13 Each	1.40	2.00	2.30	3.15	5.40	7.75	10.50	15.50	23.00	----
Galvanized Each	2.80	4.00	4.60	6.30	10.80	15.50	21.00	31.00	46.00	----

ELBOWS 45°.

Size Inches	¼	⅜	½	¾	1	1¼	1½	2	2½	3
Fig. 21 Each	.06	.06	.07	.10	.12	.19	.24	.34	.60	.90
Galvanized Each	.12	.12	.14	.20	.24	.38	.48	.68	1.20	1.80
Size Inches	3½	4	4½	5	6	7	8	9	10	12
Fig. 21 Each	1.25	1.45	2.20	2.50	3.45	5.90	8.50	11.25	17.00	25.00
Galvanized Each	2.50	2.90	4.40	5.00	6.90	11.80	17.00	22.50	34.00	50.00

SIDE OUTLET ELBOWS.

Size Inches	½	¾	1	1¼	1½	2	2½	3	3½
Fig. 22 Each	.18	.24	.30	.48	.60	.84	1.50	2.25	3.15
Galvanized Each	.36	.48	.60	.96	1.20	1.68	3.00	4.50	6.30
Size Inches	4	4½	5	6	7	8	9	10	12
Fig. 22 Each	3.60	5.25	6.00	8.25	14.00	20.00	26.00	40.00	60.00
Galvanized Each	7.20	10.50	12.00	16.50	28.00	40.00	52.00	80.00	120.00

STRAIGHT TEES.

Size Inches	¼	⅜	½	¾	1	1¼	1½	2	2½	3
Fig. 31 Each	.08	.08	.09	.12	.15	.23	.29	.41	.73	1.10
Galvanized Each	.16	.16	.18	.24	.30	.46	.58	.82	1.46	2.20
Size Inches	3½	4	4½	5	6	7	8	9	10	12
Fig. 31 Each	1.50	1.75	2.55	3.00	4.00	6.80	9.75	13.00	19.50	29.00
Galvanized Each	3.00	3.50	5.10	6.00	8.00	13.60	19.50	26.00	39.00	58.00

REDUCING TEES.

Size Inches	⅜	½	¾	1	1¼	1½	2	2½	3	3½
Fig. 32 Each	.09	.10	.14	.17	.27	.33	.47	.83	1.25	1.75
Galvanized Each	.18	.20	.28	.34	.54	.66	.94	1.66	2.50	3.50
Size Inches	4	4½	5	6	7	8	9	10	12	----
Fig. 32 Each	2.00	2.95	3.50	4.60	7.80	11.25	15.00	22.50	33.50	----
Galvanized Each	4.00	5.90	7.00	9.20	15.60	22.50	30.00	45.00	67.00	----

The largest opening of Reducing Fittings determines the list price.

CROSSES.

STRAIGHT SIZES.

Size Inches	⅜	½	¾	1	1¼	1½	2	2½	3	3½
Fig. 51 Each	.15	.16	.22	.27	.42	.53	.75	1.30	2.00	2.70
Galvanized Each	.30	.32	.44	.54	.84	1.06	1.50	2.60	4.00	5.40
Size Inches	4	4½	5	6	7	8	9	10	12	----
Fig. 51 Each	3.15	4.60	5.50	7.25	12.25	17.50	23.50	35.00	52.50	----
Galvanized Each	6.30	9.20	11.00	14.50	24.50	35.00	47.00	70.00	105.00	----

REDUCING SIZES.

Size Inches	½	¾	1	1¼	1½	2	2½	3	3½
Fig. 52 Each	.18	.25	.30	.46	.60	.83	1.45	2.20	3.00
Galvanized Each	.36	.50	.60	.92	1.20	1.66	2.90	4.40	6.00
Size Inches	4	4½	5	6	7	8	9	10	12
Fig. 52 Each	3.50	5.10	6.00	8.00	13.50	19.25	26.00	38.50	58.00
Galvanized Each	7.00	10.20	12.00	16.00	27.00	38.50	52.00	77.00	116.00

The largest opening of Reducing Fittings determines the list price.

REDUCING COUPLINGS.

REGULAR PATTERN.

Size Inches	2	2½	3	3½	4	4½	5	6	7	8	9	10	12
Fig. 61 Each	.43	.60	.80	1.00	1.35	1.85	2.00	2.70	5.35	6.75	8.35	10.00	15.00
Galvanized	.86	1.20	1.60	2.00	2.70	3.70	4.00	5.40	10.70	13.50	16.70	20.00	30.00

ECCENTRIC REDUCING COUPLINGS.

Size Inches	1	1¼	1½	2	2½	3	3½	4
Fig. 62 Each	.50	.55	.72	1.00	1.50	2.40	3.00	4.00
Size Inches	4½	5	6	7	8	9	10	12
Fig. 62 Each	5.00	6.00	8.00	9.00	11.00	12.50	14.00	18.00

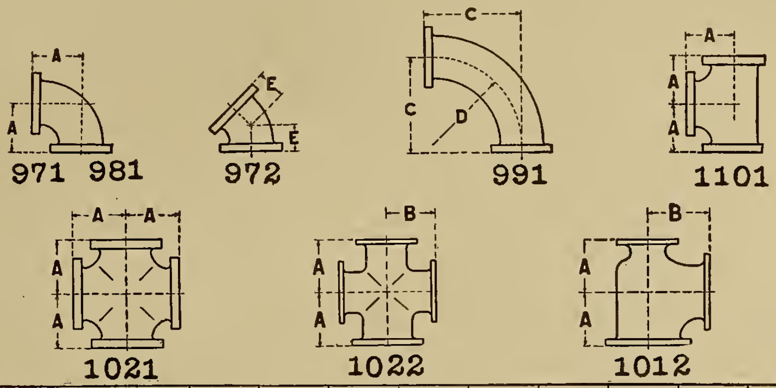
The largest opening of Reducing Fittings determines the list price.

Discount 60 and 10

DIMENSIONS OF

EXTRA HEAVY CAST IRON FLANGED FITTINGS.

For Steam Working Pressures up to 250 Lbs.



Size ....Inches	1¼	1½	2	2½	3	3½	4	4½	5
AA-Face to Face......	8½	9	10	11	12	13	14	15	16
A-Center to Face	4¼	4½	5	5½	6	6½	7	7½	8
B-Center to Face	4¼	4½	5	5½	6	6½	7	7½	8
C-Center to Face	....	....	6½	7	7¾	8½	9	9½	10¼
D-Radius	....	....	5¼	5⅝	6¼	6⅞	7⅜	7¾	8½
E-Center to Face	2½	2¾	3	3½	3½	4	4½	4½	5
Size ....Inches	6	7	8	9	10	12	14	15	16
AA-Face to Face......	17	18	20	21	23	26	29	30	32
A-Center to Face	8½	9	10	10½	11½	13	14½	15	16
B-Center to Face	8½	9	10	10½	11½	13	14½	15	16
C-Center to Face	11½	12¾	14	15¼	16½	19	21½	22¾	24
D-Radius	9⅝	10⅞	12	13	14⅛	16½	18⅞	20	21¼
E-Center to Face	5½	6	6	6½	7	8	8	8½	9

All Reducing Fittings, 1¼ inches to 9 inches inclusive, are the same dimensions, Center to Face, as straight sizes. For Dimensions of Reducing Fittings 10 inches and larger, see lower table.

Size ....Inches	10	12	14	15	16	18	20	22	24
Size of Outlets	6 and Smaller	8 and Smaller	9 and Smaller	9 and Smaller	10 and Smaller	12 and Smaller	14 and Smaller	15 and Smaller	15 and Smaller
AA-Face to Face of Run	18	21	22	23	24	27	30	30	30
A-Center to Face of Run	9	10½	11	11½	12	13½	15	15	15
B-Cen. to Face of Outlet	11	12½	13½	13½	15	16½	17½	18½	19½

EXTRA HEAVY.
CAST IRON FLANGED FITTINGS.
250 Lbs. Working Pressure.

Straight Tee. — FIGURE 1011.

Size. Inches.	Faced Only. Each.	Faced and Drilled. Each.	Center to Face. Inches.	Face to Face. Inches.	Diam. of Flanges. Inches.
2	7.00	8.50	5	10	6½
2½	7.25	9.00	5½	11	7½
3	8.25	10.00	6	12	8¼
3½	9.50	11.25	6½	13	9
4	10.50	13.50	7	14	10
4½	13.00	16.00	7½	15	10½
5	14.25	17.25	8	16	11
6	17.50	20.50	8½	17	12½
7	23.00	28.75	9	18	14
8	29.00	34.75	10	20	15
9	38.00	44.00	10½	21	16¼
10	46.50	52.50	11½	23	17½
12	64.00	73.00	13	26	20
14	84.00	95.00	14½	29	22½
15	105.00	117.00	15	30	23½
16	122.00	135.00	16	32	25

Reducing Tee. — FIGURE 1012.

Size. Inches.	Faced Only. Each.	Faced and Drilled. Each.	Center to Face. Inches.	Face to Face. Inches.
2	8.00	9.50	For Dimensions, see page 107.	
2½	8.25	10.00		
3	9.50	11.25		
3½	11.00	12.75		
4	12.00	15.00		
4½	15.00	18.00		
5	16.25	19.25		
6	20.00	23.00		
7	26.50	32.00		
8	33.50	39.00		
9	43.50	50.00		
10	53.50	60.00		
12	74.00	83.00		
14	96.00	107.00		
15	120.00	132.00		
16	140.00	153.00		

Long Radius Elbows.

Size. Inches.	Faced Only. Each.	Faced and Drilled. Each.	Diameter of Flanges. Inches.	Radius. Inches.	Center to Face. Inches.
2	9.50	11.50	6½	5¼	6½
2½	10.00	12.50	7½	5⅝	7
3	11.50	14.00	8¼	6¼	7¾
3½	13.00	15.50	9	6⅞	8½
4	14.50	18.50	10	7⅜	9
4½	18.00	22.00	10½	7¾	9½
5	19.50	23.50	11	8½	10¼
6	24.00	28.00	12½	9⅝	11½
7	32.00	39.50	14	10⅞	12¾
8	40.00	47.50	15	12	14
9	52.00	60.00	16¼	13	15¼
10	64.00	72.00	17½	14⅛	16½
12	88.00	100.00	20	16½	19
14	116.00	130.00	22½	18⅞	21½
15	144.00	160.00	23½	20	22¾
16	168.00	186.00	25	21¼	24

90° Elbow. — FIGURE 971.

Size. Inches.	Faced Only. Each.	Faced and Drilled. Each.	Center to Face. Inches.
2	4.75	5.75	5
2½	5.00	6.25	5½
3	5.75	7.00	6
3½	6.50	7.75	6½
4	7.25	9.25	7
4½	9.00	11.00	7½
5	9.75	11.75	8
6	12.00	14.00	8½
7	16.00	19.75	9
8	20.00	23.75	10
9	26.00	30.00	10½
10	32.00	36.00	11½
12	44.00	50.00	13
14	58.00	65.00	14½
15	72.00	80.00	15
16	84.00	93.00	16

45° Elbow. — FIGURE 972.

Size. Inches.	Faced Only. Each.	Faced and Drilled. Each.	Center to Face. Inches.	Diam. of Flanges. Inches.
2	5.25	6.25	3	6½
2½	5.50	6.75	3½	7½
3	6.25	7.50	3½	8¼
3½	7.25	8.50	4	9
4	8.00	10.00	4½	10
4½	10.00	12.00	4½	10½
5	10.75	12.75	5	11
6	13.00	15.00	5½	12½
7	16.00	19.75	6	14
8	20.00	23.75	6	15
9	26.00	30.00	6½	16¼
10	32.00	36.00	7	17½
12	44.00	50.00	8	20
14	58.00	65.00	8	22½
15	72.00	80.00	8½	23½
16	84.00	93.00	9	25

Straight Cross. — FIGURE 1021.

Size. Inches.	Faced Only. Each.	Faced and Drilled. Each.	Center to Face. Inches.	Face to Face. Inches.	Diam. of Flanges. Inches.
2	9.50	11.50	5	10	6½
2½	10.00	12.50	5½	11	7½
3	11.50	14.00	6	12	8¼
3½	13.00	15.50	6½	13	9
4	14.50	18.50	7	14	10
4½	18.00	22.00	7½	15	10½
5	19.50	23.50	8	16	11
6	24.00	28.00	8½	17	12½
7	32.00	39.50	9	18	14
8	40.00	47.50	10	20	15
9	52.00	60.00	10½	21	16¼
10	64.00	72.00	11½	23	17½
12	88.00	100.00	13	26	20
14	116.00	130.00	14½	29	22½
15	144.00	160.00	15	30	23½
16	168.00	186.00	16	32	25

Reducing Cross. — FIGURE 1022.

Size. Inches.	Faced Only. Each.	Faced and Drilled. Each.	Center to Face. Inches.	Face to Face. Inches.
2	11.00	13.00	For Dimensions, see page 1	
2½	11.50	14.00		
3	13.25	15.75		
3½	15.00	17.50		
4	16.75	20.75		
4½	20.75	25.00		
5	22.50	26.50		
6	27.50	31.50		
7	37.00	45.00		
8	46.00	53.50		
9	60.00	68.00		
10	74.00	82.00		
12	100.00	112.00		
14	132.00	146.00		
15	165.00	180.00		
16	193.00	210.00		

Discount on all Flanged Fittings 60 per cent.

EXTRA HEAVY.

CAST IRON FLANGED FITTINGS.

250 Lbs. Working Pressure.

Reducing Taper Elbows.

Size. Inches.	FIGURE 981. Faced Each.	FIGURE 981. Faced and Drilled. Each.	Diameter of Flanges. Inches.	Center to Face. Inches.	Size. Inches.	FIGURE 981. Faced Each.	FIGURE 981. Faced and Drilled. Each.	Diameter of Flanges. Inches.	Center to Face. Inches.
2 x 1¼	9.50	11.50	6½ x 5	5	7 x 5	32.00	39.50	14 x 11	9
2 x 1½	9.50	11.50	6½ x 6	5	7 x 6	32.00	39.50	14 x 12½	9
2½ x 1½	10.00	12.50	7½ x 6	5½	8 x 4	40.00	47.50	15 x 10	10
2½ x 2	10.00	12.50	7½ x 6½	5½	8 x 5	40.00	47.50	15 x 11	10
3 x 1½	11.50	14.00	8¼ x 6	6	8 x 6	40.00	47.50	15 x 12½	10
3 x 2	11.50	14.00	8¼ x 6½	6	8 x 7	40.00	47.50	15 x 14	10
3 x 2½	11.50	14.00	8¼ x 7½	6	10 x 5	64.00	72.00	17½ x 11	11½
3½ x 2	13.00	15.50	9 x 6½	6½	10 x 6	64.00	72.00	17½ x 12½	11½
3½ x 2½	13.00	15.50	9 x 7½	6½	10 x 8	64.00	72.00	17½ x 15	11½
3½ x 3	13.00	15.50	9 x 8¼	6½	12 x 7	88.00	100.00	20 x 14	13
4 x 2	14.50	18.50	10 x 6½	7	12 x 8	88.00	100.00	20 x 15	13
4 x 2½	14.50	18.50	10 x 7½	7	12 x 9	88.00	100.00	20 x 16¼	13
4 x 3	14.50	18.50	10 x 8¼	7	12 x 10	88.00	100.00	20 x 17½	13
4 x 3½	14.50	18.50	10 x 9	7	14 x 6	116.00	130.00	22½ x 12½	14½
5 x 2½	19.50	23.50	11 x 7½	8	14 x 10	116.00	130.00	22½ x 17½	14½
5 x 3	19.50	23.50	11 x 8¼	8	14 x 12	116.00	130.00	22½ x 20	14½
5 x 4	19.50	23.50	11 x 10	8	15 x 6	144.00	160.00	23½ x 12½	15
6 x 3	24.00	28.00	12½ x 8¼	8½	15 x 10	144.00	160.00	23½ x 17½	15
6 x 3½	24.00	28.00	12½ x 9	8½	15 x 12	144.00	160.00	23½ x 20	15
6 x 4	24.00	28.00	12½ x 10	8½	16 x 8	168.00	186.00	25 x 15	16
6 x 4½	24.00	28.00	12½ x 10½	8½	16 x 10	168.00	186.00	25 x 17½	16
6 x 5	24.00	28.00	12½ x 11	8½	16 x 12	168.00	186.00	25 x 20	16
7 x 4	32.00	39.50	14 x 10	9	16 x 14	168.00	186.00	25 x 22½	16

Pipe Size and O. D. of Flange. Inches.	Screwed Flange. Faced Only. Each.	Screwed Flange. Faced and Drilled. Each.	Blank Flange. Faced Only. Each.	Blank Flange. Faced and Drilled. Each.	Price of Bolts per Set for One Joint.	Threading Pipe, Making On and Refacing, Not Including Flange. Net Each.
1 x 4½	1.00	1.25	----	----	.20	.60
1¼ x 5	1.05	1.35	----	----	.20	.60
1½ x 6	1.10	1.40	----	----	.25	.65
2 x 6½	1.20	1.50	1.40	1.70	.25	.70
2½ x 7½	1.40	2.00	1.60	2.20	.40	.75
3 x 8¼	1.60	2.25	1.85	2.50	.55	.85
3½ x 9	1.80	2.50	2.10	2.80	.55	.90
4 x 10	2.15	3.00	2.50	3.35	.80	.95
4½ x 10½	2.50	3.35	2.90	3.75	.80	1.00
5 x 11	2.80	3.65	3.25	4.10	.80	1.10
6 x 12½	3.20	4.00	3.70	4.50	1.15	1.25
7 x 14	4.35	5.75	5.00	6.40	1.80	1.35
8 x 15	5.00	6.50	5.75	7.25	1.80	1.55
9 x 16¼	6.75	8.25	7.75	9.25	1.80	1.80
10 x 17½	7.75	9.25	9.00	10.60	2.60	2.00
12 x 20	10.50	12.50	14.00	16.00	2.75	2.75
14 x 22½	13.75	16.00	17.50	19.75	3.60	3.50
15 x 23½	18.00	21.00	22.50	25.50	4.75	3.75
16 x 25	22.50	26.00	28.00	31.50	4.75	4.75
18 x 27	27.50	31.00	33.00	36.50	5.60	7.00
20 x 29½	30.00	34.00	36.00	40.00	8.30	8.25
22 x 31½	33.75	39.00	41.00	46.00	10.00	9.50
24 x 34¼	41.00	46.00	50.00	55.00	10.00	11.00

Discount on all Flanged Fittings 60 per cent.

EXTRA HEAVY.

CAST IRON SCREWED FITTINGS.

250 Lbs. Working Pressure.

FLANGE UNIONS.

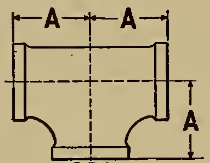
Size. Inches.	Diameter of Flanges.	Diameter of Bolt Circle.	Number of Bolts.	Price. Each.
½	3	2	4	.60
¾	3¼	2¼	4	.70
1	3⅝	2⅝	4	.80
1¼	4⅛	3⅛	4	1.00
1½	4⅝	3½	4	1.15
2	5½	4⅛	5	1.50
2½	6⅛	4⅝	5	1.90
3	6⅞	5⅜	6	2.25
3½	7½	6	6	2.70
4	8	6½	7	3.15
4½	8¾	7⅛	8	4.00
5	9½	7¾	8	4.75
6	10⅞	9⅛	9	6.00
7	12	10¼	10	8.25
8	13¼	11⅜	10	10.50

LONG SWEEP FITTINGS.

CAST IRON.

For Steam Working Pressures to 125 Lbs.
For Water Working Pressures to 175 Lbs.

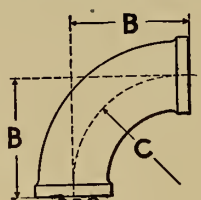
DOUBLE SWEEP TEES.



291

Size ____________________ Inches	1	1¼	1½	2	2½	3	3½	4
Fig. 291, Tees ______________ Each	.64	.80	1.10	1.60	2.40	4.50	6.50	7.00
Reducing Tees ______________ Each	.96	1.20	1.65	2.40	3.60	6.75	9.75	10.50
A-Center to Face _________ Inches	2¼	2⅝	3	3⅝	4¾	5½	5¾	6⅛
Size ____________________ Inches	4½	5	6	7	8	9	10	12
Fig. 291, Tees ______________ Each	11.00	13.00	17.50	26.00	34.00	51.00	60.00	80.00
Reducing Tees ______________ Each	16.50	19.50	26.25	39.00	51.00	76.50	90.00	120.00
A-Center to Face _________ Inches	6¼	7	7½	8⅞	9½	10¾	11½	12¾

EXTRA LONG SWEEP ELBOWS.

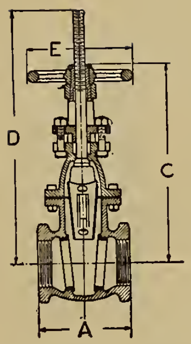


292

Size ____________________ Inches	1	1¼	1½	2	2½	3	3½	4
Fig. 292, Elbows ___________ Each	.50	.70	.90	1.20	2.00	3.00	4.00	5.00
B-Center to Face _________ Inches	3 1/16	3⅜	4	5½	6⅛	7¼	8¼	10⅝
C-Radius ________________ Inches	2½	2¾	3⅜	4¾	5¼	5⅞	6¾	9⅛
Size ____________________ Inches	4½	5	6	7	8	9	10	12
Fig. 292, Elbows ___________ Each	7.00	9.00	13.00	20.00	28.00	34.00	40.00	60.00
B-Center to Face _________ Inches	10⅞	11⅛	13	14½	18¼	21½	24¾	31
C-Radius ________________ Inches	9¼	9½	11⅜	12¾	16½	19¾	22⅞	28¾

Straight sizes furnished galvanized at double the above lists, and regular discounts.

Discount 60 and 10



DIMENSIONS OF MEDIUM PRESSURE GATE VALVES.

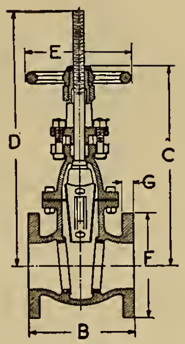


Fig. 1521. Screwed.

Fig. 1522. Flanged.

Size ---------------------------Ins.	2	2½	3	3½	4	4½	5	6
A-Fig. 1521 -------------------Ins.	5½	6	7¼	7½	7¾	8¼	8½	8¾
B-Fig. 1522 -------------------Ins.	7½	8	9½	10	10½	11	11½	12
C-Center to Top of Wheel -------Ins.	11½	12½	15	16⅜	19	20	22	25¼
D-Center to Top of Spindle, Open-Ins.	14	15½	18½	20½	23¾	25	28	32
E-Diameter of Wheel -----------Ins.	6½	6½	7½	7½	9	9	10	12
F-Diameter of Flange -----------Ins.	6½	7½	8¼	9	10	10½	11	12½
G-Thickness of Flange ----------Ins.	⅞	1	1⅛	1³⁄₁₆	1¼	1⁵⁄₁₆	1⅜	1⁷⁄₁₆
Size ---------------------------Ins.	7	8	9	10	12	----	----	----
B-Fig. 1522 -------------------Ins.	12½	13½	14	15	16	----	----	----
C-Center to Top of Wheel -------Ins.	28	32	34	39	44	----	----	----
D-Center to Top of Spindle, Open-Ins.	36	41	44	50	57	----	----	----
E-Diameter of Wheel -----------Ins.	12	14	14	16	18	----	----	----
F-Diameter of Flange -----------Ins.	14	15	16¼	17½	20	----	----	----
G-Thickness of Flange ----------Ins.	1½	1⅝	1¾	1⅞	2	----	----	----

Size-------------Inches	2	2½	3	3½	4	4½	5	6
Fig. 1521 ---------Each	23.00	25.00	29.00	35.00	40.00	50.00	54.00	65.00
Fig. 1522 ---------Each	25.50	27.50	32.00	38.00	45.00	55.00	59.00	72.00
Drilling ----------Each	.75	.75	.75	1.00	1.25	1.50	1.50	1.75
Size-------------Inches	7	*8	9	10	12	----	----	----
Fig. 1522 ---------Each	97.00	117.00	152.00	178.00	225.00	----	----	----
Drilling ----------Each	2.25	2.25	2.50	2.50	3.50	----	----	----

This valve is suitable for pressure up to 175 lbs.
The discount is 50 and 5 per cent.

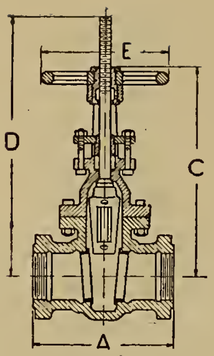


Fig. 1581.

DIMENSIONS OF
EXTRA HEAVY
OUTSIDE SCREW AND YOKE GATE VALVES.

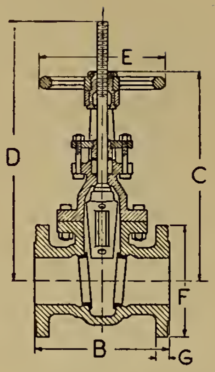


Fig. 1582.

Size .... Inches	2½	3	3½	4	4½	5	6
A-Fig. 1581 .... Inches	8⅛	9½	11⅜	12⅜	14	15⅜	16¼
B-Fig. 1582 .... Inches	9½	11⅛	11⅞	12	13¼	15	15⅞
C-Center to Top .... Inches	13½	15⅛	17⅛	18⅞	23⅜	23⅜	25⅜
D Center to Top of Stem, Open .... Inches	16¼	18⅜	21	23⅜	29¼	29¼	31⅞
E-Diameter of Wheel .... Inches	8	10	10	11	11	12	13
F-Diameter of Flange .... Inches	7½	8¼	9	10	10½	11	12½
G-Thickness of Flange .... Inches	1	1⅛	1 3/16	1¼	1 5/16	1⅜	1 7/16
Size .... Inches	7	8	9	10	12	----	----
B-Fig. 1582 .... Inches	16¼	16½	17	18	19¾	----	----
C-Center to Top .... Inches	29¾	32½	36½	39⅜	45¼	----	----
D-Center to Top of Spindle, Open .... Inches	37½	41⅛	46½	50½	58½	----	----
E-Diameter of Wheel .... Inches	15	15	16	16	18	----	----
F-Diameter of Flange .... Inches	14	15	16¼	17½	20	----	----
G-Thickness of Flange .... Inches	1½	1⅝	1¾	1⅞	2	----	----

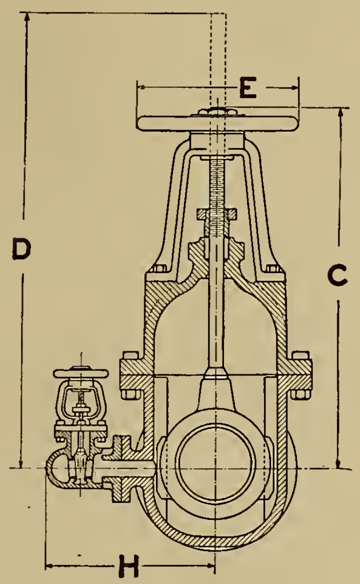
Size .... Inches	2½	3	3½	4	4½	5	6
Fig. 1581 .... Each	41.00	54.00	67.00	72.00	92.00	100.00	115.00
Fig. 1582 .... Each	43.50	57.00	70.00	77.00	97.00	105.00	122.00
Drilling .... Each	.75	.75	1.00	1.25	1.50	1.50	1.75
Size .... Inches	7	*8	9	10	12	----	----
Fig. 1582 .... Each	147.00	187.00	257.00	283.00	390.00	----	----
Drilling .... Each	2.25	2.25	2.50	2.50	3.50	----	----

Discount 60 per cent.

DIMENSIONS OF

EXTRA HEAVY GATE VALVES.

WITH BY-PASS.



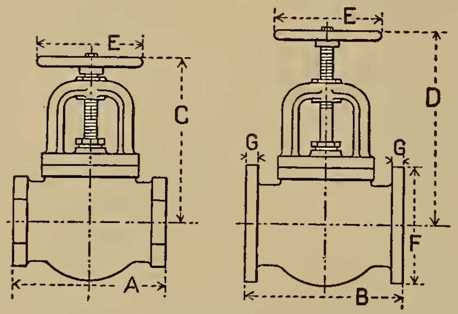
Size .... Inches	6	7	8	9	● 10
Face to Face, Flanged .... Inches	15⅞	16¼	16½	17	18
C-Center to Top .... Inches	25⅜	29¾	32½	36½	39⅜
E-Diameter of Wheel .... Inches	13	15	15	16	16
D-Center to Top of Spindle, open .... Inches	32	38	41	46	50
H-Center to Outside of By-Pass .... Inches	14	15	16	16½	17½
Diameter of Flange .... Inches	12½	14	15	16¼	17½
Thickness of Flange .... Inches	1$\frac{7}{16}$	1½	1⅝	1¾	1⅞
Size of By-Pass .... Inches	1½	1½	1½	1½	1½
Size .... Inches	12	14	15	16	----
Face to Face, Flanged .... Inches	19¾	21½	22½	24	----
C-Center to Top .... Inches	45¼	50½	52½	58	----
E-Diameter of Wheel .... Inches	18	22	22	24	----
D-Center to Top of Spindle, open .... Inches	58½	66	69	75½	----
H-Center to Outside of By-Pass .... Inches	20	21	21½	27	----
Diameter of Flange .... Inches	20	22½	23½	25	----
Thickness of Flange .... Inches	2	2⅛	2$\frac{3}{16}$	2¼	----
Size of By-Pass .... Inches	2	2	2	3	

Size .... Inches	*6	7	8	9	10	12
Fig. 1601 .... Each	170.00	195.00	240.00	310.00	335.00	455 00
Drilling .... Each	1.75	2.25	2.25	2.50	2.50	3.50
Size .... Inches	14	15	16	----	----	----
Fig. 1601 .... Each	580.00	680.00	825.00	----	----	----
Drilling .... Each	4.00	4.00	5.00	----	----	----

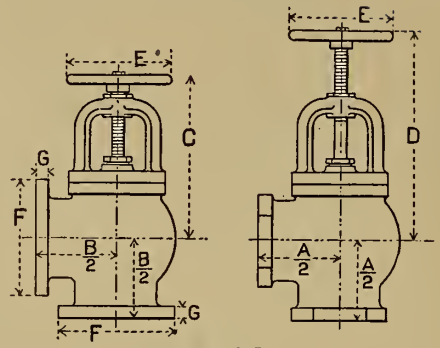
* 6-inch Valves have Bronze Spindles.
Larger sizes, Steel Spindles, Nickel Plated.

Discount 60 per cent.

DIMENSIONS OF
EXTRA HEAVY
IRON BODY GLOBE AND ANGLE VALVES.



1981



1982

Size .... Inches	2½	3	3½	4	4½	5	6
A-End to End .... Inches	10½	11½	12¾	13	14	14¾	16½
A/2-Center to End .... Inches	5¼	5¾	6⅜	6½	7	7⅜	8¼
B-Face to Face .... Inches	11½	12½	13½	14	15	15¾	17½
B/2-Center to Face .... Inches	5¾	6¼	6¾	7	7½	7⅞	8¾
C-Center to Top, Closed .... Inches	13	14	15¾	16¾	17½	18	20
D-Center to Top, Open .... Inches	14½	15¾	17¾	19	20	20¾	23½
E-Diameter of Wheel .... Inches	8	9	9	12	12	14	16
F-Diameter of Flange .... Inches	7½	8¼	9	10	10½	11	12½
G-Thickness of Flange .... Inches	1	1⅛	1³⁄₁₆	1¼	1⁵⁄₁₆	1⅜	1⁷⁄₁₆
Size .... Inches	7	8	10	12	----	----	----
B-Face to Face .... Inches	19¼	21	24½	28	----	----	----
B/2-Center to Face .... Inches	9⅝	10½	12¼	14	----	----	----
C-Center to Top, Closed .... Inches	21½	25	28	32	----	----	----
D-Center to Top, Open .... Inches	25¼	29	33	38	----	----	----
E-Diameter of Wheel .... Inches	16	20	24	30	----	----	----
F-Diameter of Flange .... Inches	14	15	17½	20	----	----	----
G-Thickness of Flange .... Inches	1½	1⅝	1⅞	2	----	----	----

Size .... Inches	2½	3	3½	4
Globe or Angle Valves, Screwed Ends .... Each	33.00	37.00	42.00	46.00
Globe or Angle Valves, Flanged Ends .... Each	35.00	40.00	45.00	50.00
Fig. 1981, Drilling .... Each	.75	.75	1.00	1.25
Fig. 1982, Drilling .... Each	1.25	1.25	1.50	1.75
Size .... Inches	4½	5	6	----
Globe or Angle Valves, Screwed Ends .... Each	56.00	61.00	75.00	----
Globe or Angle Valves, Flanged Ends .... Each	60.00	65.00	80.00	----
Fig. 1981, Drilling .... Each	1.50	1.50	1.75	----
Fig. 1982, Drilling .... Each	2.00	2.00	2.50	----
Size .... Inches	7	8	10	12
Globe or Angle Valves, Flanged Ends .... Each	100.00	120.00	200.00	300.00
Fig. 1981, Drilling .... Each	2.25	2.25	2.50	3.50
Fig. 1982, Drilling .... Each	3.00	3.00	3.50	5.00

Discount 60 per cent.

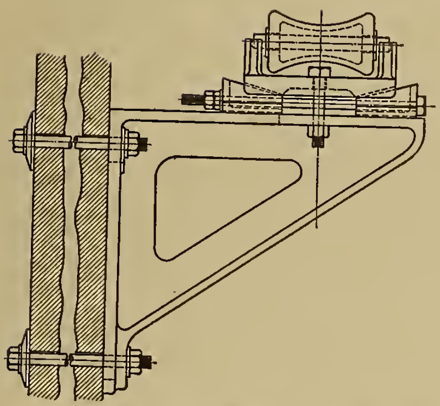
DRILLING TEMPLATES

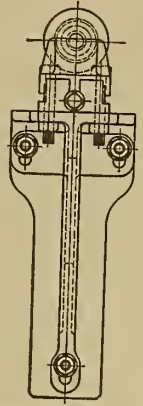
FOR

FLANGED VALVES, FLANGED FITTINGS AND FLANGES.

250 Lbs. Working Pressure.

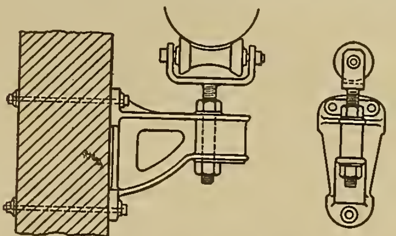
Size. Inches.	Diameter of Flanges.	Thickness of Flanges.	Bolt Circle.	Number of Bolts.	Size of Bolts.	Length of Bolts.
1	4½	11/16	3¼	4	½	2
1¼	5	¾	3¾	4	½	2¼
1½	6	13/16	4½	4	⅝	2½
2	6½	⅞	5	4	⅝	2½
2½	7½	1	5⅞	4	¾	3
3	8¼	1⅛	6⅝	8	¾	3
3½	9	1³⁄16	7¼	8	¾	3¼
4	10	1¼	7⅞	8	¾	3½
4½	10½	1⁵⁄16	8½	8	¾	3½
5	11	1⅜	9¼	8	¾	3¾
6	12½	1⁷⁄16	10⅝	12	¾	3¾
7	14	1½	11⅞	12	⅞	4
8	15	1⅝	13	12	⅞	4¼
9	16¼	1¾	14	12	1	4½
10	17½	1⅞	15¼	16	1	4¾
12	20	2	17¾	16	1	5
14	22½	2⅛	20	20	1	5¼
15	23½	2³⁄16	21	20	1⅛	5½
16	25	2¼	22½	20	1⅛	5¾
18	27	2⅜	24½	24	1⅛	6
20	29½	2½	26¾	24	1¼	6½
22	31½	2⅝	28¾	28	1¼	6¾
24	34¼	2¾	31¼	28	1⅜	7





From Wall to Center of Pipe, Adjustable............Inches	15 to 19
Horizontal Center between Wall Bolts............Inches	8
Vertical Center between Wall Bolts............Inches	18¾
From Wall to End of Bracket............Inches	27
Price, including Wall Bolts............Each	28.00

Size Pipe............Ins.	2	2½	3	4	5	6	7
Size Base............Ins.	6½ x 6½	7 x 7	7 x 7	8 x 8	8 x 8	10 x 10	10 x 10
Floor to Center of Pipe..Ins.	4¹¹⁄16	5⁵⁄16	5⅝	6	6⅝	8	8¹¹⁄16
Each............	1.50	1.75	1.90	2.25	2.40	3.25	3.50
Size Pipe............Ins.	8	9	10	12	14	15	16
Size Base............Ins.	14	14	14	19	19	19	19
Floor to Center of Pipe..Ins.	10⅞	11⁷⁄16	12⁸⁄16	15⅝	16¼	16⅞	17½
Each............	6.25	6.50	6.50	13.00	14.00	14.50	14.50



Size Pipe	Number............	00	0	1	2	3	4
	Wall to Center of Pipe..Ins.	6 to 9	9 to 12	12 to 15	15 to 18	18 to 21	21 to 24
5	Each............	17.00	18.00	18.50	19.00	19.50	22.00
6	Each............	17.50	18.50	19.00	19.50	20.00	22.50
7	Each............	18.00	19.00	19.50	20.00	20.50	23.00
8	Each............	18.00	19.00	19.50	20.00	20.50	23.00
9	Each............	18.50	19.50	20.00	20.50	21.00	23.50
10	Each............	18.50	19.50	20.00	20.50	21.00	23.50
12	Each............	19.00	21.00	21.50	22.00	23.00	25.00
14	Each............	20.00	22.00	22.50	23.00	23.50	25.00

Discount on Cast Iron Rolls, Chains and Wall Brackets 37½ per cent.

SEAMLESS DRAWN BRASS PIPE.

STANDARD IRON PIPE SIZES.

Iron Pipe Sizes.	Actual Outside Diameter.	Actual Inside Diameter.	Approximate Wt. per Foot Pounds.*	Iron Pipe Sizes.	Actual Outside Diameter.	Actual Inside Diameter.	Approximate Wt. per Foot Pounds.*
1/8	.405	.281	.25	2½	2.875	2.5	5.75
¼	.540	.375	.43	3	3.500	3.062	8.30
3/8	.675	.494	.62	3½	4.000	3.5	10.90
½	.840	.625	.90	4	4.500	4.	12.70
¾	1.050	.822	1.25	4½	5.000	4.5	13.90
1	1.315	1.062	1.70	5	5.563	5.062	15.75
1¼	1.660	1.368	2.50	6	6.625	6.125	18.31
1½	1.900	1.6	3.00	7	7.625	7.062	23.73
2	2.375	2.062	4.00	8	8.620	7.980	29.88

EXTRA HEAVY IRON PIPE SIZES.

Iron Pipe Sizes.	Actual Outside Diameter.	Actual Inside Diameter.	Approximate Wt. per Foot Pounds.*	Iron Pipe Sizes.	Actual Outside Diameter.	Actual Inside Diameter.	Approximate Wt. per Foot Pounds.*
1/8	.405	.205	.370	2	2.375	1.933	5.460
¼	.540	.294	.625	2½	2.875	2.315	8.300
3/8	.675	.421	.830	3	3.500	2.892	11.200
½	.840	.542	1.200	3½	4.00	3.358	13.700
¾	1.050	.736	1.660	4	4.50	3.818	16.500
1	1.315	.951	2.360	5	5.563	4.813	22.800
1¼	1.660	1.272	3.300	6	6.625	5.750	32.00
1½	1.900	1.494	4.250	----	------	------	------

* Some variation must be expected in these weights.
Stock lengths of 1/8 inch to 2 inches Standard Weight Pipe average 16 feet in length; 2½ inches to 4 inches, 14 feet to 16 feet; 5 inches to 6 inches, 10 feet to 12 feet.
Stock lengths of Extra Heavy Pipe run somewhat shorter than Standard Weight.

BRASS FITTINGS.

EXTRA HEAVY—IRON PIPE SIZE.

CAST IRON PATTERN.

For 250 Lbs. Steam Working Pressure.

TEES, CROSSES, AND Y BENDS.

Size ....Inches	¼	3/8	½	¾	1	1¼	1½	2	2½	3	3½	4
Tees ....Each	.35	.40	.65	1.00	1.35	2.00	3.00	4.50	7.50	11.00	16.50	20.00
Tees, Reducing...Each	--	.46	.75	1.15	1.55	2.30	3.45	5.20	8.60	12.65	---	22.00
Crosses ....Each	--	--	.90	1.30	1.80	2.75	4.00	5.25	9.00	14.00	21.00	27.00
Crosses, Red .....Each	--	--	1.04	1.50	2.10	3.15	4.60	6.00	10.35	16.00	24.00	30.00
Y Bends..........Each	--	--	1.30	1.35	2.25	2.90	4.25	6.50	9.60	13.25	22.50	30.00

Finished Fittings at double above lists.

ELBOWS.

Size ....Inches	¼	3/8	½	¾	1	1¼	1½	2	2½	3	3½	4
Elbows...........Each	.25	.28	.36	.70	1.00	1.50	2.00	3.00	5.50	8.50	12.50	16.00
Elbows, Red ..... Each	--	.32	.42	.80	1.15	1.72	2.30	3.45	6.30	9.75	14.50	18.50
Elbows, R. and L. Each	--	.32	.42	.80	1.15	1.72	2.30	3.45	6.30	9.75	---	---
Elbows, 45° ......Each	.35	.40	.43	.84	1.20	1.80	2.40	3.60	6.60	10.20	15.50	20.00

Finished Fittings at double above lists.

BRASS FLANGED FITTINGS

STANDARD WEIGHT.

For 125 Lbs.

Size ....Inches	2	2½	3	3½	4	4½	5	6
Elbows, 90°, Faced ....Each	25.00	33.75	43.75	58.75	68.00	78.00	93.00	123.00
90°, Faced and Drilled ....Each	26.00	35.00	45.00	60.00	70.00	80.00	95.00	125.00
Elbows, 45°, Faced ....Each	27.50	37.25	47.75	63.75	73.00	83.00	98.00	133.00
45°, Faced and Drilled ....Each	28.50	38.50	49.00	65.00	75.00	85.00	100.00	135.00
Tees, Faced ....Each	37.50	50.75	65.75	88.25	102.00	117.00	137.00	187.00
Faced and Drilled ....Each	39.00	52.50	67.50	90.00	105.00	120.00	140.00	190.00
Crosses, Faced ....Each	50.00	67.50	87.50	117.50	136.00	156.00	186.00	246.00
Faced and Drilled ....Each	52.00	70.00	90.00	120.00	140.00	160.00	190.00	250.00
Companion Flanges, Faced ...Each	10.75	12.50	15.50	19.25	24.25	26.75	29.00	36.50
Faced and Drilled ....Each	11.00	13.00	16.00	20.00	25.00	27.50	30.00	37.50

Dimensions same as Standard Weight Cast Iron Fittings.
Reducing sizes to order at special prices.

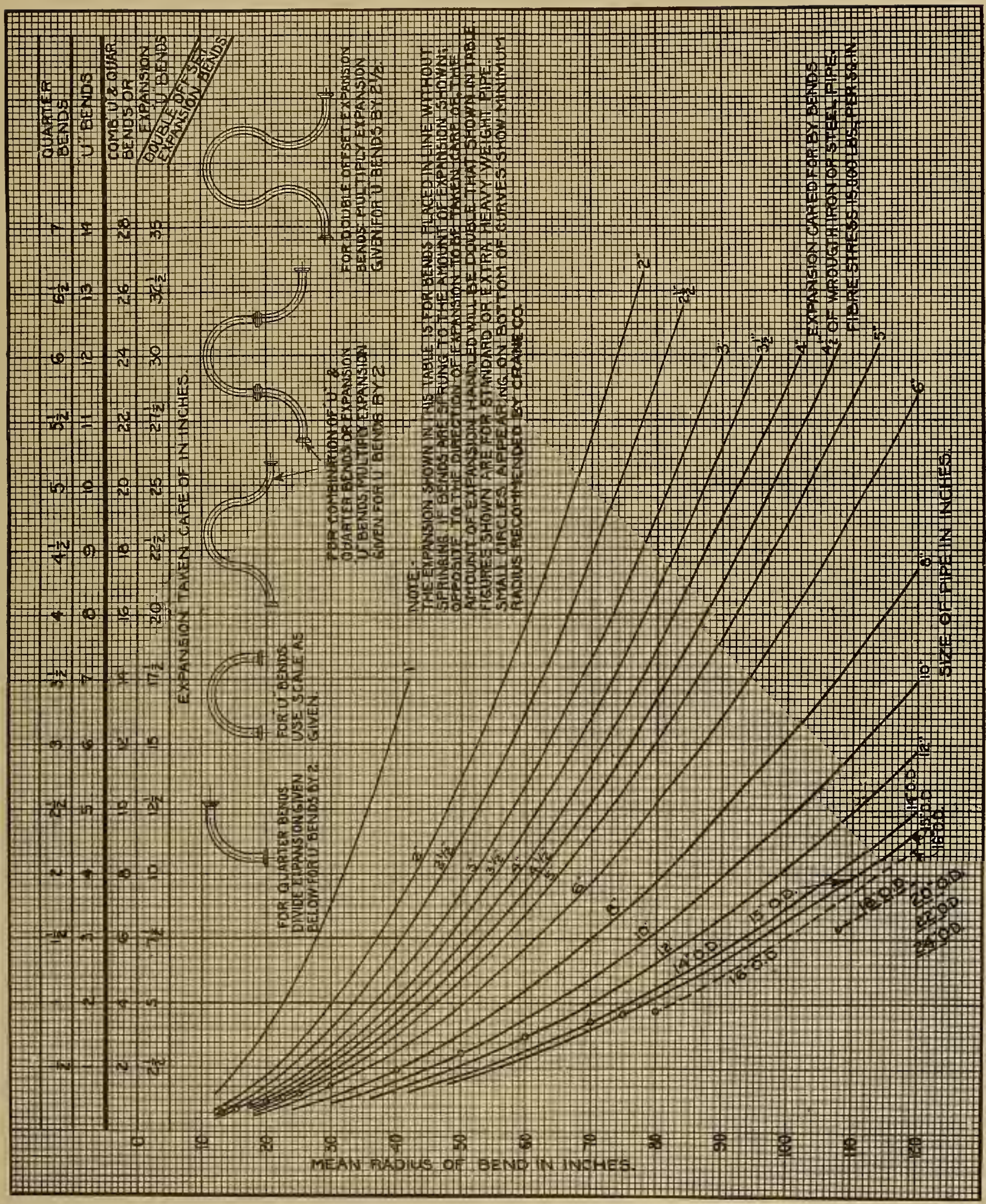
EXTRA HEAVY.

For 250 Lbs. Steam Working Pressure.

Size ....Inches	2	2½	3	3½	4	4½	5	6
Elbows, 90°, Faced ....Each	25.00	33.75	43.75	58.75	68.00	78.00	93.00	123.00
90°, Faced and Drilled ....Each	26.00	35.00	45.00	60.00	70.00	80.00	96.00	125.00
Elbows, 45°, Faced ....Each	27.50	37.25	47.75	63.75	73.00	83.00	98.00	133.00
45°, Faced and Drilled ....Each	28.50	38.50	49.00	65.00	75.00	85.00	100.00	135.00
Tees, Faced...................Each	37.50	50.75	65.75	88.25	102.00	117.00	137.00	187.00
Faced and Drilled ....Each	39.00	52.50	67.50	90.00	105.00	120.00	140.00	190.00
Crosses, Faced ....Each	50.00	67.50	87.50	117.50	136.00	156.00	186.00	246.00
Faced and Drilled ....Each	52.00	70.00	90.00	120.00	140.00	160.00	190.00	250.00
Companion Flanges, Faced...Each	10.75	12.50	15.50	19.25	24.25	26.75	29.00	36.50
Faced and Drilled ....Each	11.00	13.00	16.00	20.00	25.00	27.50	30.00	37.50

Dimensions same as Extra Heavy Cast Iron Fittings.
Reducing sizes to order at special prices,

Discount on all brass fittings flanged or screwed, 65 per cent.



In figuring the cost of a bent pipe, add to the net cost of the pipe and flanger the following for each bend of 90° or less

For pipe size	6″	7″	8″	9″	10″	12″
add per bend	$8	$9	$12	$13	$16	$26

CAST IRON PIPE

Cast iron pipe may be used to convey cooling water to the power house. This pipe comes in lengths of about twelve feet and has a bell on one end and a spigot on the other. The joint between the bell and spigot is made by pouring in melted lead and then calking with a blunt chisel.

A table giving the weights of cast iron pipe is convenient in figuring costs which are taken at a certain rate per ton, the price depending upon the price of pig iron. The price is between $20 and $25 a ton.

DIMENSIONS OF CAST IRON PIPE

Standard adopted by American Water Works Association.

The weight per length refers to length of 12 feet and includes allowance for bell and spigot.

	Class A, 100 ft. Head			Class B, 200 ft. Head			Class C, 300 ft. Head		
Nominal inside dia.	Thickness In.	Weight Lbs. Ft.	Weight Lbs. Length	Thickness In.	Weight Lbs. Ft.	Weight Lbs. Length	Thickness In.	Weight Lbs. Ft.	Weight Lbs. Length
8	.46	42.9	515	.51	47.5	570	.56	52.1	625
10	.50	57.1	685	.57	63.8	765	.62	70.8	850
12	.54	72.5	870	.62	82.1	985	.68	91.7	1100
14	.57	89.6	1075	.66	102.5	1230	.74	116.7	1400
16	.60	108.3	1300	.70	125.0	1500	.80	143.8	1725
18	.64	129.2	1550	.75	150.0	1800	.87	175.0	2100
20	.67	150.0	1800	.80	175.0	2100	.92	208.2	2500
24	.76	204.2	2450	.89	233.3	2800	1.04	279.2	3350
30	.88	192.7	3500	1.03	333.3	4000	1.20	400.0	4800
36	.99	391.7	4700	1.15	454.2	5450	1.36	545.8	6550

PIPE COVERING

The heat radiated from a bare pipe is about 3 B. T. U. per hour per square foot of *pipe surface* per degree difference in temperature between the steam inside the pipe and the air in the room.

The saving made by coverings of different thickness is shown by the figures below which apply to a 5″ pipe:

	Bare Pipe No Covering	Covering ½″ Thick	Covering 1″ Thick	Covering 1¼″ Thick	Covering 1½″ Thick
B. T. U. loss per hour per square foot of surface of 5″ pipe per degree diff. in temperature	3.00	.67	.43	.37	.33

The B. T. U. loss per square foot of *pipe surface* per hour per degree difference in temperature gradually increases for the covered pipes as the diameter of the pipe decreases, the values for a 2″ pipe being about 20 per cent greater than the values given above. For sizes over 5″ diameter the values gradually decrease until at 10″ diameter, the figures are 10 per cent lower than those given.

The efficiency of a covering, or the percentage of heat saved, varies slightly with different coverings of the same thickness, in general, however, a covering 3″ thick may be assumed to have an efficiency of 88 per cent and one, 1¼″ thick, 85 per cent.

The saving per year due to covering an 8″ header 200 feet long supplied with steam at 170 lbs. absolute superheated 100° may be figured thus.

For high pressure steam, 100 to 150 lbs., the *Double Layer Double Standard Thickness* sectional covering should be used. This covering should be applied by the broken joint method, each set of sections being thoroughly wired in place. Outside of the sections ½″ of plastic should be added and the whole covered with 8 oz. canvas sewed on.

The fittings should be covered with blocks and plastic or with all plastic of a thickness to correspond with the covering on the pipe.

The flanges should be covered with removable flange covering made up of blocks and plastic, 2″ thick on special netting, and covered with canvas to match the pipe covering.

Exhaust piping, feed piping, drips, etc., should be covered with *Standard Sectional Covering* and with regular canvas jacket.

For standard thickness of covering apply 45 per cent discount to list given. For fittings apply 45 per cent. Note that the cost of covering the flanges on an elbow or tee is not included in the cost as given for elbow or tee and is to be added.

For superheated steam lines the 3″ thickness is advisable. Figure a discount on 3″ thickness of 35 per cent. This makes the price of the 3″ thickness per lineal foot all installed with canvas jacket:

$1.43 for	4″ pipe	$2.05 for	8″ pipe
1.63 "	5″ "	2.37 "	10″ "
1.76 "	6″ "	2.67 "	12″ "
1.89 "	7″ "		

For fittings covered with 3″ thickness use regular fitting prices as per list for *Standard Thickness* and add 10 per cent.

Removable flange covers for this thickness of covering would be 2″ thick and the cost of these covers is not included in the cost of elbows and tees as given in the price list.

The price of these flange covers installed is 10 per cent above the figures given in the right hand column.

Boiler drums should be covered with blocks 2″ thick and ½″ of plastic added. Such covering costs 35 cents per square foot area of the external surface of the covering.

For smoke flues, flues leading to economizers, etc., blocks 1" thick should be wired on and covered with ½" of plastic. This costs 25 cents a square foot.

The outside diameter of 8" pipe is 8.625", the circumference in feet is 2.258.

The total surface of 200 ft. of pipe is 451.6 sq. ft. and the B. T. U. loss per year is $365 \times 24 \times 451.6 \times 3 \times (468.5 - 68.5) = 4{,}747{,}200{,}000$, assuming room to be 68.5° F.

If 10,000 B. T. U. are utilized by the boiler per lb. of coal burned, the coal required to supply this loss would be 474,200 lbs. or 237.1 tons. At $4.50 per ton this amounts to $1067.

If a covering 3" thick is used, an efficiency of 88 per cent may be assumed. The saving due to the covering becomes $.88 \times 1067 = \$939$ per year.

The first cost of the covering would be for the 200 feet of pipe 200 × $2.05 = $410
10 pairs of flanges 10 × $2.53 = 25.30

$435.30

The covering would more than pay for itself in six months.

The cost of a covering may be figured from the price list, noting the discount given on the different items.

PRICE LIST OF 85% MAGNESIA AND ALL OTHER SECTIONAL COVERINGS

Inside Diameter of Pipe	Standard Thickness of Covering	Price per Lineal Foot Canvas Jacketed	Thickness of Covering	Price per Lineal Foot Canvas Jacketed	Thickness of Covering	Price per Lineal Foot Canvas Jacketed
½"	⅞"	$.22	1½"	$.46	2"	$.75
¾"	⅞"	.24	1½"	.49	2"	.80
1"	⅞"	.27	1½"	.52	2"	.85
1¼"	⅞"	.30	1½"	.56	2"	.90
1½"	⅞"	.33	1½"	.60	2"	.95
2"	1 1/32"	.36	1½"	.64	2"	1.00
2½"	1 1/32"	.40	1½"	.70	2"	1.05
3"	1 1/32"	.45	1½"	.76	2"	1.15
3½"	1 1/32"	.50	1½"	.82	2"	1.25
4"	1⅛"	.60	1½"	.88	2"	1.35
4½"	1⅛"	.65	1½"	.94	2"	1.45
5"	1⅛"	.70	1½"	1.00	2"	1.55
6"	1⅛"	.80	1½"	1.10	2"	1.70
7"	1¼"	1.00	1½"	1.20	2"	1.85
8"	1¼"	1.10	1½"	1.35	2"	2.00
9"	1¼"	1.20	1½"	1.50	2"	2.20
10"	1¼"	1.30	1½"	1.65	2"	2.40
12"*	1½"	1.85	1½"	1.85	2"	2.70
14"	1½"	2.10	1½"	2.10	2"	3.00
16"	1½"	2.35	1½"	2.35	2"	3.30
18"	1½"	2.60	1½"	2.60	2"	3.60
20"	1½"	2.85	1½"	2.85	2"	4.00
24"	1½"	3.30	1½"	3.30	2"	4.50
30"	1½"	4.00	1½"	4.00	2"	5.50

*All coverings above 10 in. furnished in segment form; jackets not included in the prices.

PRICE LIST OF 85% MAGNESIA AND ALL OTHER SECTIONAL COVERINGS — Cont.

Double Layer. Double Standard Thickness	Price per Lineal Foot Canvas Jacketed	Double layer. Total Thickness 3 in.	Price per Lineal Foot Canvas Jacketed	Block List Double Layer. Double Standard Thickness	Price per Lineal Foot Canvas Jacketed	Double layer. Total Thickness 3 in.	Price per Lineal Foot Canvas Jacketed
1¾″	$.65	3″	$1.20	½″	$.27	2⅛″	$.64
1¾″	.70	3″	1.35	¾″	.27	2¼″	.68
1¾″	.75	3″	1.40	⅞″	.30	2⅜″	.72
1¾″	.80	3″	1.45	1″	.30	2½″	.75
1¾″	.85	3″	1.55	1⅛″	.34	2⅝″	.79
2 1/16″	.90	3″	1.65	1¼″	.38	2¾″	.83
2 1/16″	1.00	3″	1.75	1⅜″	.42	2⅞″	.87
2 1/16″	1.10	3″	1.90	1½″	.45	3″	.90
2 1/16″	1.20	3″	2.05	1⅝″	.49	3¼″	.98
2¼″	1.40	3″	2.20	1¾″	.53	3½″	1.05
2¼″	1.50	3″	2.35	1⅞″	.57	4	1.20
2¼″	1.60	3″	2.50	2″	.60		
2¼″	1.80	3″	2.70				
2½″	2.25	3″	2.90				
2½″	2.50	3″	3.15				
2½″	2.70	3″	3.40				
2½″	2.90	3″	3.65				
3″	4.10	3″	4.10				
3″	4.60	3″	4.60				
3″	5.10	3″	5.10				
3″	5.60	3″	5.60				
3″	6.00	3″	6.00				
3″	7.00	3″	7.00				
3″	8.40	3″	8.40				

Sizes of Fittings	Elbows	Tees	Crosses	G. Valves	Flange Covers
½″	$.30	$.36	$.48	$.54	$.50
¾″	.30	.36	.48	.54	.50
1″	.30	.36	.48	.54	.50
1¼″	.30	.36	.48	.54	.50
1½″	.30	.36	.48	.54	.50
2″	.36	.42	.54	.60	.60
2½″	.42	.48	.60	.78	.70
3″	.48	.54	.70	.96	.80
3½″	.54	.60	.80	1.20	.90
4″	.60	.75	.95	1.50	1.00
4½″	.72	.90	1.10	1.85	1.30
5″	.90	1.20	1.50	2.25	1.60
6″	1.30	1.60	2.00	2.80	1.90
7″	1.80	2.20	2.80	3.60	2.20
8″	2.40	3.00	3.60	4.40	2.50
9″	3.00	3.80	4.40	5.30	2.90
10″	3.60	4.60	5.20	6.20	3.30

SPECIFICATIONS

The specifications for a Condensing Equipment for a 1500 K. W. Low Pressure Steam Turbine; for Automatic Pump and Receiver; for Direct Acting Boiler Feed Pumps and for Turbine Driven Centrifugal Boiler Feed Pumps were furnished by Mr. B. R. T. Collins '88.

SPECIFICATIONS
FOR
CONDENSING EQUIPMENT

Including

SURFACE CONDENSER, HOT WELL PUMP, DRY VACUUM PUMP

1. NUMBER WANTED. One.
2. TYPE. Surface condenser with separate wet and dry air pumps.
3. CAPACITY.
   Amount of steam to be condensed, 000 lbs. per hour.
   Temperature of injection water, 70° Fahrenheit.
   Absolute pressure in condenser, 2 inches of mercury or 28 inches vacuum referred to a 30-inch barometer.
4. CHARACTER OF CIRCULATING WATER.
   Fresh river water.
5. SOURCE OF CIRCULATING WATER.
   From factory water supply system. Any quantity up to 000 gallons per min. at any pressure required.
6. RELATIVE LOCATION OF CONDENSING EQUIPMENT AND TURBINE.
   The surface condenser with the dry air pump will be located directly beneath the horizontal turbine to which it will be connected and as near to it as practicable. The wet or hot well pump can be located as much below this level as required. The exhaust outlet of the turbine will look down.
7. EQUIPMENT TO BE FURNISHED.
   The equipment to be furnished includes surface condenser, wet or hot well pump and dry air or dry vacuum pump required to give the results stated under "CAPACITY."
   The hot well pump shall be of the duplex direct-acting steam driven type.
   The dry vacuum pump shall be of the rotative steam driven type.
   The condenser proper, hot well and dry vacuum pumps are described in detail under separate specifications following.

SPECIFICATIONS FOR SURFACE CONDENSER

1. NUMBER WANTED. One.
2. CONSTRUCTION.
   This surface condenser shall contain not less than 000 sq. ft. of cooling surface. The shell and heads are to be furnished with openings for the exhaust steam, circulating water inlet and discharge, dry air and condensed steam, of sizes and locations approved by the Engineer.

The tube heads are to be of rolled brass.
The tubes are to be seamless drawn brass of the following composition:

Copper	60%
Zinc	40%

Every tube is to be inspected for faults on both inside and outside and all tubes showing any indication of imperfection of any kind are to be rejected.
The condenser is to be tested under 25 lbs. per sq. in. cold water pressure applied in both steam and water spaces before shipment from the factory and made tight.
The interior of the shell is to be carefully painted with two coats of anti-rust metallic paint. The whole exterior is to be scraped, filled and painted with the best lead and oil paint before leaving the shops.
All interior bolting in contact with the circulating water is to be of composition unless otherwise specified.

3. Bolts, Etc.
Bolts, nuts and screws shall be of the United States standard.

4. Finish.
All castings shall be carefully dressed down, filled and painted with the best quality of paint.

5. Drilling.
All flanges shall be faced and drilled in accordance with Manufacturers' Standard for flanges and drilling.

6. Design, Material and Workmanship.
The design shall be such as to insure safe, reliable and economical operation.
The material and workmanship shall be the best of their respective kinds.
The contractor shall furnish, without charge, F. O. B. cars, a duplicate of any part that may prove defective in material or workmanship within one year after the condensing equipment has been started.

7. Drawings.
Bidder shall submit in connection with his proposal an outline drawing to scale and a description of the condenser he proposes to furnish, giving in detail the design, and arrangement made for removal of parts and for repairs.

8. Condenser Data.
The bidder shall furnish the following data on each condenser:

Number of tubes ....
Length of tubes..............ft. ....in.
Outside diameter of tubes......................in.
Thickness of tubes ....No. 18 B. W. G.
Thickness of tube heads ....in.
Cooling surface ....sq. ft.
Material of tubes ....
Area exhaust opening ....
Size of circulating water inlet opening ....in.
Size of circulating water discharge opening ...in.
Size dry air opening ....in.
Approximate finished weight ....lbs.
Approximate shipping weight ....lbs.

SPECIFICATION FOR DIRECT ACTING HOT WELL PUMP

1. Number Wanted. One.
2. Type. Horizontal duplex piston type.
3. Kind of Service.
   Removing condensed steam from surface condenser.
4. Working Steam Pressure. 175 lbs. per sq. in. gage.
5. Minimum Steam Pressure. 125 lbs. per sq. in. gage.
6. Steam Temperature. 527.6° F. (approx.) or 150° superheat.
7. Back Pressure. 17 lbs. per sq. in. absolute.
8. Discharge Water Pressure. Not over 15 ft. head.
9. Capacity.
   The pump shall be capable of delivering at least............gallons of water per minute under the conditions of operation as described in this specification.
10. Water End Fittings.
   Bronze cylinder linings, piston rods, pistons, stuffing box glands, valve seats, bolts, plates and springs. Hard rubber valves for 212° F. water.
11. Lubrication.
   There shall be furnished with the pump one (1) pint "Detroit" lubricator.
12. Drilling.
   All flanges shall be faced and drilled in accordance with Manufacturers' Standard for flanges and drillings.
13. Material and Workmanship.
   The material and workmanship shall be the best of their respective kinds. The Contractor shall furnish without charge F. O. B., a duplicate of any part that may prove defective in material, or workmanship one year after the pump has been started.
14. Drawings.
   Bidder shall submit in connection with his proposal, an outline drawing to scale and a description of the pump he proposes to furnish, giving all necessary details.
15. Pump Data.
   Bidder shall furnish the following data on the pump:

Diameter steam cylinder..........................ins.
Diameter water cylinder ....ins.
Length of stroke ....ins.
Diameter steam inlet ....ins.
Diameter exhaust outlet ....ins.
Diameter suction ....ins.
Diameter discharge ....ins.
Approximate finished weight ....lbs.
Approximate shipping weight ....lbs.

SPECIFICATION FOR ROTATIVE DRY VACUUM PUMP

1. Number Wanted. One.
2. Type.
   Horizontal, crank and fly wheel rotative dry vacuum pump.
3. Kind of Service.
   Removing non-condensible vapors from condenser.
4. Speed.
   Not over 150 R. P. M. Piston speed not over 300 feet per minute.
5. Working Steam Pressure. 175 lbs. per sq. in. gage.
6. Minimum Steam Pressure. 125 lbs. per sq. in. gage.
7. Steam Temperature. 527.6° F. (approx.) or 150° superheat.

8. Back Pressure. 17 lbs. per sq. inch absolute.
9. Capacity.
The capacity of this air pump shall be at least 35 times the volume of the condensed steam.
10. Cylinders.
The cylinders shall be of close-grained cast iron.
The air cylinder shall be strong enough to withstand a normal working pressure of 50 lbs. per sq. in. and the steam cylinder shall be strong enough to withstand a steam pressure of 200 lbs. per sq. in. after being rebored ¼″ in diameter without causing the tensile strength in the metal to exceed 2500 lbs. per sq. in. The steam cylinder shall be lagged with 85% carbonate of magnesia held on with Russia iron covering. Provision shall be made on both the steam and air cylinders for attaching indicators. All cylinders shall be provided with drip cocks. The steam and air ports shall be of ample size to allow easy and quick action of the steam and air. All parts shall be so arranged as to be readily accessible.
11. Steam Valves and Valve Motion.
Throttle valve will be furnished by the purchaser.
The steam valve shall be of the balanced type with provision for taking up wear.
12. Air Valves.
The air valves shall be of a suitable type for obtaining the greatest vacuum under the conditions herein specified.
13. Lubrication.
Ample lubrication shall be provided for all parts subject to wear. There shall be furnished with pump one (1) nickle plated, 2 qt., two feed Richardson sight feed lubricator with divided reservoir for supplying two different kinds of oil, one for the steam cylinder and the other for the air cylinder.
14. Wrenches.
One full set of wrenches shall be furnished with the pump.
15. Bolts, Etc.
Bolts, nuts and screws shall be of the United States standard.
16. Finish.
The working parts of the pump shall be highly finished, all exposed metal parts usually polished, such as cylinder cover and the faces of flywheels, shall be smooth turned, and together with all castings carefully filled and painted with the best quality of paint.
17. Drilling.
All flanges shall be faced and drilled in accordance with Manufacturers' Standard.
18. Design, Material and Workmanship.
The design shall provide ample bearing surfaces, abundant lubrication and strong rugged parts and shall insure safe, reliable and economical operation.
The material and workmanship shall be the best of their respective kinds. The contractor shall furnish without charge f. o. b. a duplicate of any part that may prove defective in material or workmanship within one year after the pump has been started.
19. Drawings.
Bidder shall submit in connection with his proposal, an outline drawing to scale and a description of the pump he proposes to furnish, giving in detail the design of pistons, plungers, valves, and arrangement made for removal of parts and for repairs.
20. Pump Data.
Bidder shall furnish the following data on the pump:

Dimensions:

Diameter steam cylinder.........................ins.
Diameter air cylinder ....ins.
Length of stroke ....ins.

Floor Space:
Length . . . . ft. . . . . ins.
Width . . . . ft. . . . . ins.
Height . . . . ft. . . . . ins.

Pipe Opening:
Steam . . . . ins. Suction . . . . ins.
Exhaust . . . . ins. Discharge . . . . ins.

Steam End:
Type of steam valve . . . .
Area admission ports . . . . sq. ins.
Area exhaust ports . . . . sq. ins.

Air End:
Type of air valve . . . .
Area admission ports . . . . sq. ins.
Area exhaust ports . . . . sq. ins.

Bearings:
Diameter main bearings . . . . ins.
Length main bearings . . . . ins.
Diameter crank pin . . . . ins.
Length crank pin . . . . ins.
Diameter wrist-pin . . . . ins.
Length wrist-pin . . . . ins.
Diameter of shaft . . . . ins.
Dimensions of cross-head shoes . . . . ins.

Governor:
Type of governor . . . .

Flywheel:
Diameter . . . . ft. ins.
Width of face . . . . ins.

Approximate Weights:
Finished weight . . . . lbs.
Shipping weight . . . . lbs.

SPECIFICATION FOR 1500 K. W. MAXIMUM RATED HORIZONTAL LOW PRESSURE STEAM TURBINE

Steam End

1. Number Wanted. One.
2. Type. Horizontal low pressure condensing.
3. Kind of Service. Direct connected to generator supplying current for factory motors and motor-generators or rotaries.
4. Speed. Revolutions per minute.
5. Steam Pressure at Throttle. Fifteen pounds absolute. Alternate proposition on turbine suitable to use both fifteen pounds absolute and 175 pounds per sq. in. gage.
6. Steam Temperature at Throttle. Temperature due to pressure given above. No superheat.
7. Back Pressure. 2″ of mercury absolute.
8. Regulation. The speed of the turbine shall not vary more than 2½% above or below the normal speed at any load less than 500 K. W. Maximum speed variation where full load is thrown on or off instantaneously will not exceed. . . . . %. The contractor shall furnish as part of the turbine an electrical synchronizing device for varying the speed of the turbine from the switchboard.

9. CAPACITY. When operating condensing under the condition herein stated the turbine shall furnish power to generate,—

   1500 K. W. continuously;
   2000 K. W. momentarily.

10. THROTTLE VALVE. The throttle valve shall be of the Schutte and Koerting make, actuated at a speed of 10% above normal by a safety governor.
11. BOLTS, NUTS, ETC. Bolts, nuts and screws shall be of the United States Standard.
12. FINISH. The turbine as a whole shall be highly polished, all exposed metal parts polished and castings carefully dressed down, filled and painted with the best quality of paint.
13. DRILLING. All flanges shall be faced and drilled in accordance with Manufacturers' Standard for flanges and drilling.
14. STEAM CONSUMPTION. The turbine shall consume not more than the amounts of steam given below when developing the corresponding kilowatts, running at a speed of........ revolutions per minute, with a steam pressure of fifteen pounds absolute per sq. in. and exhausting against a back pressure of 2 inches of mercury absolute. The steam pressure shall be the averaged measured just outside the throttle valve, and the back pressure shall be measured in the exhaust pipe near the turbine.

Steam Consumption	*Pounds per K. W. hour*
K. W.	............................lbs. per K. W. H.
375	............................lbs. per K. W. H.
750	............................lbs. per K. W. H.
1125	............................lbs. per K. W. H.
1500	............................lbs. per K. W. H.

15. ERECTION. The contractor shall provide for the superintendence of erection of the turbine, all common labor to be provided by the purchaser. The contractor agrees to have the turbine and generator erected ready for operation within 15 days after their arrival at destination provided no delays are caused by the purchaser.
16. DESIGN, MATERIAL AND WORKMANSHIP. The design shall provide ample bearing surfaces, abundant lubrication and strong rugged parts, and shall insure safe, reliable and economical operation, and without undue heating or vibration. The material and workmanship shall be the best of their respective kinds. The contractor shall furnish, without charge, f. o. b., a duplicate of any part that may prove defective in material or workmanship within one year after the turbine has been started.
17. DRAWINGS. Bidder shall submit in connection with his proposal an outline drawing to scale and a description of the turbine he proposes to furnish, giving in detail the arrangements made for the removal of parts for repairs.
18. TURBINE DATA. Bidder shall furnish the following data on the turbine:

DIMENSIONS:
- Length ....
- Width ....
- Height ....

PIPING:
- Steam ....
- Exhaust ....

WEIGHT:
- Weights of heaviest part ....
- Weight of heaviest part to be moved when making ordinary repairs ....
- Shipping weight ....
- Finished weight ....

GENERATOR END

1. Number Wanted. One.
2. Type. Revolving field.
3. Kind of Service. Supplying current for factory motors and motor-generators or rotaries.
4. Speed. Revolutions per minute......................
5. Number of Poles........................
6. Frequency. 60 cycles per second.
7. Phase. Three phase.
8. Voltage. 480 at no load.
   480 at full load, 80% power factor.
9. Regulation. The regulation of generator when operating at 100% load and 80% power factor shall not exceed................%. By "regulation" is meant the rise in potential of generator when specified load at specified power factor is thrown off.
10. Capacity. The generator shall develop:
    1500 K. W. continuously.
    2000 K. W. momentarily.
    Generator shall be capable of developing K. W. as above, at voltage specified above and at any power factor not less than 80%.
11. Amperes. Full load current................amperes per phase.
12. Temperature Rise. Shall not exceed the following:
    When generating continuously at 1500 K. W.
    480 volts.
    80% Power Factor.

Field and armature by thermometer	50 deg. C.
Collector rings and brushes by thermometer	50 deg. C.
Bearings and other parts by thermometer	50 deg. C.

13. Style of Field Winding. Separately excited.
14. Excitation. Excitation of separately excited fields shall be by direct current at 125 V. It shall not be necessary to raise excitation above 125 V. in order to maintain voltage specified above on the generator with 1500 K. W. load and 80% power factor.
15. Rheostat. A hand operated rheostat shall be furnished in field circuit to control the voltage.
16. Field Discharge Resistance. A suitable field discharge resistance shall be furnished.
17. Rheostat Mechanism. The generator field rheostat shall be furnished with hand wheel and chain operating mechanism suitable for mounting on switchboard panel.
18. Parallel Operation. The generator shall be designed so that it may be operated in parallel with other machines of similar type, of the same or different size, or inductive or non-inductive loads without seriously disturbing the regulation of any of the machines, or affecting the lights on the line.
19. Insulation Test. The ohmic resistance and dielectric strength of the insulation shall meet the requirements of the latest report of the Committee on Standardization of the American Institute of Electrical Engineers.
20. Generator Data. Bidder shall furnish the following data on generator:
    Maximum voltage that can be obtained from generator at 100% load and 80% power factor will be..............volts.
    The commercial efficiency of the generator will be as follows:
    ....% at ¼ load.
    ....% at ½ load.
    ....% at ¾ load.
    ....% at full load.
    Exciting current at full load and 80% power factor will be..............amperes at 125 volts. Maximum current on short circuit will be..............amperes at unity power factor. Shipping weights will be as follows:
    Rotor ....pounds.
    Generator complete ....pounds.
    Heaviest piece..........................pounds.

SPECIFICATION FOR DIRECT ACTING BOILER FEED PUMPS

1. Number. Two.
2. Type. Horizontal duplex outside packed plunger.
3. Service. Boiler feed.
4. Working Steam Pressure. 175 lbs. per sq. inch gage.
5. Working Exhaust Pressure. 17 lbs. absolute.
6. Working Discharge Water Pressure. 250 lbs. per sq. inch.
7. Working Suction Head. 8 ft. above floor on which pump stands.
8. Temperature of Water. 212 deg. F.
9. Capacity. Normal capacity 250 gallons per minute for each pump. Maximum capacity 500 gallons per minute for each pump.
10. Water End Fittings. Hard, close-grained cast iron plungers, composition covered, bronze stuffing box glands, valve seats, and valves of the pot valve type.
11. Air Chambers of proper capacity and length to be furnished for both suction and discharge connections.
12. Proposal. Make proposal f. o. b.. .stating price; time before shipment; shipping weight; and enclose print showing general dimensions and sizes of all connections.

SPECIFICATION FOR TURBINE DRIVEN CENTRIFUGAL BOILER FEED PUMPS

1. Type. Multistage Centrifugal Pumps, direct connected to Steam Turbines, on common bed plate with flexible shaft coupling.
2. Number. Two.
3. Service. Boiler Feed.
4. Maximum Capacity. 500 gallons per minute for each pump.
   Capacity for most economical steam consumption,— 250 gallons per minute for each pump.
5. Working Discharge Water Pressure. 250 pounds per square inch.
6. Working Suction Head above Center of Pump Shaft. 8 ft. of water.
7. Working Steam Pressure. 175 lbs. per square inch, gage.
8. Working Exhaust Pressure. 17 lbs. absolute.
9. Make Proposal f.o. b.. .stating price; time before shipment; shipping weight; print showing general dimensions and sizes of all connections; guaranteed steam consumption of turbine at maximum rating of 500 gallons per minute, also at 250 gallons per minute in pounds per H. P. per hour and efficiency of pump at each of above capacities.

SPECIFICATION FOR AUTOMATIC PUMPS AND RECEIVERS

1. Number. Five.
2. Type. Alternate propositions on (1st) single cylinder direct acting piston type steam pump with receiver and automatic arrangement for starting and stopping pump and (2nd) horizontal duplex piston type with receiver and automatic arrangement for starting and stopping pump.
3. Service. Returning hot water drips from trap discharges, heating and curing systems, etc., to open feed water heater.
4. Working Steam Pressure. Maximum 100 per sq. inch; minimum 20 per sq. inch.
5. Working Exhaust Pressure. 17 absolute.
6. Working Discharge Water Pressure. Not over 40 ft. head including pipe friction.
7. Working Suction Head. Gravity and trap returns to receiver.
8. Temperature of Water. 150 deg. F. to 212 deg. F.
9. Capacity. Four pumps 60 gallons per minute and the fifth pump 100 gallons per minute.

10. WATER AND FITTINGS. Three 60-gallon and one 100-gallon pumps bronze cylinder linings, piston rods, pistons, stuffing box glands, valve seats, bolts, plates and springs. Hard rubber valves for 212 deg. F. water. Water piston to have metallic packing rings and also to be arranged for the use of fibrous packing if desired. One 60-gallon pump and receiver to be iron fitted throughout, no bronze whatever. (For use with water containing sulphur.)

11. PROPOSAL. Make proposal stating price for both sizes of pumps in both single and duplex types; also 60-gallon pump and receiver iron fitted throughout; time before shipment; shipping weights; prints showing general dimensions and sizes of all connections and details of float and steam regulating valve with connections between them.

SPECIFICATIONS FOR 30″ x 60″ x 60″ HORIZONTAL CROSS-COMPOUND NON-CONDENSING CORLISS ENGINE

1. NUMBER WANTED. One.
2. TYPE. Horizontal Corliss, cross-compound, non-condensing.
3. KIND OF SERVICE. Rope drive to factory line shafting. Exhausting to low pressure steam turbine.
4. INDICATED HORSE POWER:
   At lowest steam consumption ....
   At maximum load ....
5. SPEED. 80 revolutions per minute.
6. STEAM PRESSURE AT THROTTLE. 175 lbs. per sq. in. gauge.
7. STEAM TEMPERATURE AT THROTTLE. 377° F.
8. BACK PRESSURE. 17 lbs. per sq. in. absolute.
9. POINT OF CUT-OFF:
   At lowest steam consumption ....%
   At maximum load ....%
10. REGULATION. The speed of the engine shall not vary more than 2½ per cent above or below the normal speed at any load less than.............. indicated horse power.
11. CYLINDER SIZES. The dimensions of the cylinder shall be as follows:

	Diameter	Stroke
High pressure cylinder	30″	60″
Low pressure cylinder	60″	60″

12. HAND. The engine shall be right hand, that is, when standing at the high pressure cylinder and looking toward the shaft, the wheel will be on the right and the low pressure cylinder on the right of the wheel.
13. WHEEL. The wheel shall have 40 grooves for 1¾″ rope and be 18 ft. in diameter.
14. CYLINDERS. The cylinders shall be of close-grained cast iron strong enough to withstand 200 lbs. steam pressure per sq. in., after being rebored ⅜″ in diameter without causing the tensile strength in the metal to exceed 3500 lbs. per sq. in.

    It shall be lagged with 85% carbonate of magnesia held on with Russia iron covering. Provision shall be made on the cylinder for attaching indicators, and an indicator reducing motion shall be provided as part of the engine. The cylinder shall be provided with drip cocks. The steam ports shall be of ample size to allow easy and quick action of the steam.
15. VALVES. The cylinder shall be provided with relief valves of ample size and at suitable position to protect the engine from damage due to water.

    Throttle valve shall be furnished with the engine.

    The steam valves shall be of the Corliss type with separate eccentrics for the steam and exhaust valves.

16. Governors. The governor for the engine shall be of the flyball type.

17. Lubrication. Lubrication shall be by means of sight feed oil cups which shall be accessibly located and shall positively and continuously supply the main shaft bearings, crank pins, wrist pins, guides, valve parts, etc. with oil. These oil cups shall be provided with bottom connections piped to a common point ready for connection to a gravity oiling system. All pipe shall be semi-annealed iron pipe size brass pipe. All brass parts shall be polished and nickel plated.

Grease cups will be allowed only on eccentrics.

Two Richardson model "M" four-feed oil pumps shall be furnished for the cylinders.

18. Wrenches and Drawings. The following fittings shall be furnished with the engine:
1 set of forged steel wrenches.
Foundation plans for setting foundation bolts.
Drawings showing dimensions of engine and foundation.

19. Packing. The piston rod shall be packed with..............metallic packing and the valve stems with..............metallic packing.

20. Bolts, Etc. Bolts, nuts and screws shall be of the United States standard.

21. Finish. The engine as a whole shall be highly finished, all exposed metal parts polished and castings carefully dressed down, filled and painted with the best quality of paint.

22. Drilling. All flanges shall be faced and drilled in accordance with Manufacturer's Standard.

23. Steam Consumption. The engine shall consume not more than the amounts of steam shown below for each load when running at a speed of 80 revolutions per minute with a steam pressure of 175 lbs. per sq. inch above the atmosphere at a temperature as indicated below and exhausting against a back pressure of 17 lbs. per sq. inch absolute. The steam pressure shall be the average measured just outside the throttle valve and the back pressure shall be measured in the exhaust pipe near the engine.

		Steam Consumption in Pounds per I. H. P.
Load	I. H. P.	Saturated Steam
¼	....	....
½	....	....
¾	....	....
Full	....	....
1½	....	....

24. Erection. The engine shall be erected by the Contractor on foundation furnished by the Purchaser. After the engine arrives at destination the Contractor agrees to push the erection through with all reasonable promptness, working a full day force. The engine is to be erected ready for operation within 30 days after its arrival at destination.

25. Design, Material and Workmanship. The design shall provide ample bearing surfaces, abundant lubrication and strong rugged parts and shall insure safe, reliable and economical operation, and without undue heating or vibration.

The material and workmanship shall be the best of their respective kinds. The Contractor shall furnish, without charge, f. o. b............... a duplicate of any part that may prove defective in material or workmanship within one year after the engine has been started. All nuts on cylinder heads, bonnets and other parts which are subject to removal shall be case-hardened.

All connections about the engine shall be made perfectly tight and all parts of the engine made as accessible as possible and capable of ready removal for repair or replacement. All parts of the engine subject to wear shall have means provided for taking up such wear. All interchangeable parts shall be machined to gauge.

26. Drawings and Data. Bidder shall submit in connection with his proposal an outline drawing to scale and a description of the engine he proposes to furnish, giving in detail the design of cylinder, piston, governor, bearings and arrangement made for removal of parts and for repairs.

27. ENGINE DATA. Bidder shall furnish the following data on the engine:

FLOOR SPACE

Length ....ft. ....inches
Width ....ft. ....inches
Height ....ft. ....inches

PIPING

	H. P. Cyl.	L. P. Cyl.
Steam	....	..............inches
Exhaust	....	..............inches

VALVES

Type of steam valves ....
Area admission ports ....sq. in.
Area exhaust ports ....sq. in.

CONNECTING RODS

Type ....
Length ....inches

BEARINGS

	H. P.		L. P.
Diameter main bearings			....
Length main bearings			....
Diameter crank pin	H. P.	....	L. P. ....
Length crank pin	H. P.	....	L. P. ....
Diameter wrist pin	H. P.	....	L. P. ....
Length wrist pin	H. P.	....	L. P. ....
Diameter of shaft			....
Dimensions of cross-head shoes		....	....

GOVERNOR

Type of governor ....

BELT WHEEL

Diameter 18 ft. 0 inches
Width of face 56 inches

WEIGHTS

Weight of heaviest part ....lbs.
Weight of fly-wheel ....lbs.
Shipping weight of engine..............lbs.
Finished weight of engine ....lbs.

NOTICE TO CONTRACTORS

Steam Driven Centrifugal Pumping Unit for the City of........................

Sealed proposals and bids for furnishing to the City of ....Mass., and installing in the......................St., Pumping Station of the City of .... a steam turbine driven centrifugal pumping outfit, as hereinafter described, will be received by the Commission of Water and Water Works of............................at the City Hall, ...Mass., until 12M, September................, 1913.

Bids must be made in duplicate.

Each bidder must leave with his bid a properly certified check for the sum of two thousand dollars ($2,000) payable to the order of the City of ...., which check will be returned to the bidder unless forfeited as hereinafter provided.

A bond will be required, for the faithful performance of the contract, in the sum of ten thousand dollars ($10,000) of an approved surety company doing business in Massachusetts.

The bidder is requested to name the surety company which will sign his bond in case the contract is awarded him.

If notice of the acceptance of the bid shall, within twenty days after September . . . ., 1913, be given to the bidder by the Commissioner of Water and Water Works of . . . ., the bond must be furnished within six days (Sunday excepted) after such notification; and in case of the failure of the bidder after such notification to furnish the bond within said time the bid shall be considered as abandoned and the certified check accompanying the bid shall be forfeited to the city.

Each bidder is to furnish with his bid detailed description and specifications covering the apparatus he purposes to install.

He is to give also the duties (duty is here considered as the foot-pounds of water work done per million British Thermal Units) he will guarantee.

First considering the steam used by the steam turbine alone without including the steam used by either wet or dry pumps used in connection with the condensing outfit, and

Second including the steam used by these pumps with the turbine steam. The guarantees of duty to be made on a pressure at the throttle of 125 lbs. gage and on steam containing not more than one and one-half per cent moisture.

The temperature of the returns to the boiler to be taken the same as the temperature of the condensed steam leaving the condenser. If the exhaust steam from the wet and dry pumps is sent through a feed water heater and used to heat the steam condensed from the turbine on its way to the boiler, the temperature of the returns will be taken as the temperature of this feed water. The temperature of the suction water to be taken at 70°. The conditions as to head and capacity to be taken as hereinafter outlined.

Each bidder is to furnish dimensioned drawings giving the general outside measurements of the entire apparatus when assembled together with such drawings or cuts as may be necessary to show the construction of his apparatus.

The one to whom the contract is awarded is to furnish the city with a working drawing of the foundation (to be built by the City) and complete working drawings of the turbine centrifugal pumps and condensing outfit complete.

The bidder is to guarantee that all bearings and reduction gears if used will be continuously lubricated and will run continuously without over-heating.

The bidder is to agree to make at his own expense all repairs which may be made necessary through original faulty construction, design or workmanship for a period of six months after the unit goes into regular service.

Neither experimental nor unusual types of apparatus will be considered.

Each bidder must be prepared to prove to the satisfaction of the Commissioner that he has previously installed units of the type he purposes to furnish and he shall state where such units are in successful operation.

The bidder must state the general type design and builders name of any part of the unit which is not built at the works of his own company.

The bidder must give the date of delivery and the time required for the erection of the completed plant.

Payments will be made as follows: Fifty per cent of the contract price ten days after the delivery of the turbine, pumps, condensers, and accessories at the pumping station and the balance due the contractor ten days after the acceptance of the unit by the City.

The Commissioner reserves the right to reject any or all bids or to award the contract as he deems best.

The duty guaranteed, the general design and accessibility of the parts, together with the cost, will be considered in awarding this contract.

Bids in which the duty guaranteed per 1,000,000 British Thermal Units including the steam used by the condensing apparatus, falls below 92,000,000 foot-pounds will not be considered.

The bidder will submit his bid and his specifications on his own printed forms and will add to the same the following:

The Contractor will indemnify and save harmless the City from all claims against the City by mechanics, laborers, and others, for work performed or materials furnished for carrying on the contract.

The Contractor will indemnify and save harmless the City, its agents and employees, from all suits and claims against it or them, or any of them, for damages to private corporations and individuals caused by the construction of the work to be done under this contract; or for the use of any invention, patent, or patent right, material, labor or implement by the contractor, or from any act, omission or neglect by him, his agents, or employees, in carrying on the work; and the Contractor agrees that so much of the money due to him under this contract as may be considered necessary by the Commissioner may be retained by the City until all such suits or claims for damages as aforesaid shall have been settled and evidence to that effect furnished to the Commissioner.

The Contractor agrees to do such extra work as may be ordered in writing by the Commissioner, and to receive in payment for the same its reasonable cost as estimated by the Commissioner plus fifteen per cent of said estimated cost.

The Contractor agrees to make no claims for compensation for extra work unless the same is ordered in writing by the Commissioner.

The Contractor still further agrees that the Commissioner may make alterations in the work, provided that if such changes increase the cost, the contractor shall be fairly remunerated and in case they diminish the cost the proper deduction from the contract price shall be made — the amount to be paid or deducted to be determined by the Commissioner.

General Description of Pumping Unit

A steam driven turbine either directly connected to a centrifugal pump or connected through reduction gears and having a smaller stage centrifugal connected by friction clutch or other suitable device to the end of the pump shaft or to one end of the turbine shaft all mounted on a suitable bed plate is to be installed together with a water works type condenser and necessary wet and dry pumps in the . . . . .St. Pumping Station of the City of . . . . A feed water heater using the exhaust steam of the wet and dry pumps may be installed by the contractor (the one to whom the contract is awarded is hereinafter designated as the Contractor) if hereby he is able to increase the duty by raising the temperature of the returns.

This equipment is to be put in the ell at the back of the building which ell is now used as a coal pocket and storage room. There is now a large outside door at the end of the ell leading from the back yard into the basement of this building. Another large door located over this basement door at the level of the present engine room floor is to be made by the city. The turbine will have to be taken in through this new door and the condensing equipment through the basement door.

This outfit is to be erected and installed by the Contractor on a foundation built by the City in accordance with drawings furnished by the Contractor. (Foundation bolts are to be furnished by the Contractor.) The Contractor is to temporarily strengthen any floors, coal pockets, etc. he may move his machinery over and to take all responsibility during the erection of the machinery. Under no circumstances is the operation of the pumping station to be interfered with.

The City will bring steam to the throttle of the turbine. The throttle valve and safety throttle are to be furnished and erected by the Contractor. The City will connect the "suction" pipe with the intake of the condenser and will make all connections to the force mains back to the discharge end of the centrifugals. In preparation for tests of this unit the City will install a Venturi meter in each of these force mains. The Contractor is to pipe the condensed steam back to the boiler feeding apparatus and to make all other connections, not specifically referred to.

The Contractor is to provide, connect, and put in place suitable 8½″ polished brass gages with gage cocks as follows, all mounted on a gage board of mahogany or stone fastened to the wall of the room at some point to be designated by the chief engineer of the station.

Gage for pressure at throttle to be divided to 150 lbs. by one pound marks.

Gage pressure in condenser: this to be a combination pressure and vacuum: 20 lbs. pressure.

Gage for measuring pressure in force mains of large centrifugal: 120 lbs. by 1 pound marks.

Gage for measuring pressure in force mains of small centrifugal: 150 lbs. by 1 lb. marks.

Gage for showing pressure of water at intake to condenser: 50 lbs. by 1 pound marks.

A clock in a case like the gages is to be furnished by the Contractor and mounted on this gage board.

The Contractor is also to provide, connect, and put in place, a mercury column for measuring the vacuum in the condenser and thermometers in suitable wells for determining the temperature of the water entering the condensers, the temperature in each force main and the temperature of the returns from the condenser to feed pumps.

Water comes to these pumps at what has been called the "suction" side under a static head of about 23 feet, the head depending upon the level in Breed's Pond. In making calculations for duty an average value of the static head of 23 feet at the level of the main floor in the present station may be assumed. The pipe leading from Breed's Pond to the........Street Station is about one-half mile in length and is 36″ in diameter for the first third of the distance and 30″ for the remaining two-thirds of the distance. There are four elbows in this 30″ line.

The centrifugal directly connected or connected through reduction gears to the turbine shaft is to discharge 13,000,000 U. S. gallons in 24 hours into a 30″ force main about one-half mile long — practically a straight run of pipe. The static pressure at the level of the station floor of the main station is 60 lbs. The present pumping outfit is discharging water through this pipe at the rate of 10,000,000 gallons in 24 hours.

The stage centrifugal, connected to the turbine shaft or pump shaft by a friction clutch or other suitable device is to deliver 2,000,000 U. S. gallons in 24 hours to a stand pipe through about one-half mile of pipe; the first half of which is 16″ diameter and the last half 12″ diameter; all of cast iron. The static pressure at the level of the station floor of the main station is 105 lbs. Drawings of the pipe lines can be seen at the office of the City Engineer, City Hall, ..., Mass.

The two pumps will be run together the greater part of the time, the high pressure pump connected and disconnected by means of a clutch or other suitable device without stopping the turbine.

The water coming from Breed's Pond to the................Street Station varies in temperature from 35° to 80°. A temperature of 70 degrees seems a fair average. The boilers now installed are to furnish the steam for this unit. These boilers are of the horizontal Multitubular type; two in number working at 125 lb. gage. The steam from these boilers may be considered to contain not more than 1½ per cent moisture. The condenser is to be made strong enough to stand with safety 105 lb. gage pressure on the water side and 20 lb. gage pressure on the steam side.

A 2″ safety valve with whistle is to be attached to the steam side of the condenser.

The turbine is to be provided with a safety throttle quick operating trip or other suitable device, satisfactory to the commissioner to prevent speeding.

The turbine is to be provided with an outboard exhaust through a water sealed automatic relief valve. The discharge from this valve to be carried by means of spiral riveted pipe through the roof. The opening made in the roof for this pipe is to be properly flashed with copper and made tight against rain and snow.

To allow for expansion there is to be a flexible connection in the piping between the turbine and the condenser.

The pump impellers are to be of bronze on suitable non-corrosive material and unbalanced end thrust on the impellers to be avoided as far as is possible.

The impeller shafts are to be protected from corrosion by removable sleeves of composition. Composition packing glands and bronze studs are to be provided for the pumps.

The contractor is to paint all machinery and piping erected by him. Such castings as are in sight from the floor of the engine room are to be made smooth, nicely fitted at all joints and flanges, filled with a proper paint filler and painted and striped in such colors as the commissioner may direct.

The Contractor is to remove all blocking, tools or other material used by him in erecting and installing his work and to remove all debris of any nature, in and around the..............Street Pumping Station, produced by him in carrying out this contract.

SPECIFICATIONS FOR AND DESCRIPTION OF PUMPING UNIT FOR ....

LOCATION. The pumping unit is to be installed in a new building distant about 500 feet north from the pumping station on ....Pond now supplying the City of ....

FLOOR LEVEL. The building will be located on the shore of the pond. The pump room floor being from 4 to 7 feet above the level of full pond.

PUMP MOTOR. The pump is to be either a single or two stage centrifugal, driven by a 4000 volt three phase, 60 cycle alternating current motor of the external resistance, slip ring type complete with device for lifting brushes and short circuiting rings after the pump is up to speed, and all necessary starting equipment.

MOTOR. The motor must be so designed that the starting current, under given load, will not exceed full load running current.

MOTOR CHARACTERISTICS. The temperature rise of the motor when operating at normal rating with a room temperature of 25° C. is not to exceed 40° C.

ELECTRICAL SWITCHBOARD. A switchboard of slate with dull black finish with the following equipment is to be furnished and erected, all meters in black finish.

(1) One voltmeter with scale calibrated to show 4000 volts.
(2) One indicating watt meter.
(3) One ammeter with switch to show current on any of the three phases.
(4) One kilowatt hour meter.
(5) Suitable testing terminals to enable check to be made on these instruments.
(6) Available space for the instruments of the .... Electric Light Co. which will be one kilowatt hour meter and suitable testing terminals.
(7) Complete switch-operating mechanism and mounting for all switches necessary for starting and controlling the motor. The oil circuit breaker to be of remote mechanical control type.
(8) Necessary current and potential transformers for preceding equipment; also available space and mounting for the necessary current and potential transformers furnished by the.........................Electric Light Co.
(9) A 125-volt switch to control electrically operated discharge valve if such electrically operated valve is used; provision shall also be made for 125 volt lighting.

LIGHTNING PROTECTIVE APPARATUS. In addition to the preceding the following are to be furnished and separately mounted: One complete lightning arrester and choke coil outfit for one 3-phase 4000 volt circuit, (Y connected, neutral grounded at generating plant only, through low resistance); also suitable disconnecting switches for the lightning arresters and incoming circuit respectively.

CIRCUIT BREAKER. One oil circuit breaker with inverse time limit overload relay and no-voltage release, with remote mechanical control.

BUS WORK AND WIRING. All bus work and wiring necessary for connecting the motor to the switchboard and to power wires on the outer wall of the pump house, consisting of copper conductors, clamps, insulators, pins and pipe frame-work and other details necessary for the successful operating of the equipment, are to be furnished and installed by the contractor. Power wires outside of the pump house are to be installed by the....................Electric Light Co.

PUMP CAPACITY. The centrifugal pump is to discharge 8,000,000 U. S. gallons in 24 hours from a pump well with water at grade 127, through about 2180 feet of new 36″ cast iron pipe to a standpipe with water at grade 305. There is to be a hydraulically or an electrically operated valve and a check valve between the pump and the 36″ main. These valves are to be furnished and installed by the city.

HEAD. This 36″ pipe will receive an additional 8,000,000 gallons in 24 hours from a second unit in the same pumping station or from another station approximately 500 feet away. This fact is to be noted in considering the total head the pump is to work against.

IMPELLER END THRUST. The pump impeller is to be of bronze or suitable non-corrosive material, and unbalanced end thrust on the impeller is to be avoided as far as possible. The pump impeller and the pump casing shall be provided with bronze renewable wearing rings so that they may be readily replaced if necessary.

IMPELLER SHAFTS. The impeller shafts are to be protected from corrosion by removable sleeves of composition. Composition packing glands and bronze studs are to be provided for the pumps; stuffing boxes on ends of pump shall be provided with water seals.

PRIMING DEVICE. The pump is to have a water ejector or other device capable of removing air from the pump, in priming, in a period of five minutes.

DISCHARGE VALVE. A hydraulically or electrically operated valve in the discharge pipe of the pump and not over 20 feet from the discharge outlet of the pump will be installed by the City and all necessary piping, valves or wiring and switches needed for the operation of this valve are to be furnished and connected up by the contractor. This valve will be closed with the pump running at full speed preparatory to shutting down the unit.

PUMP CHARACTERISTICS. The Contractor must submit with his bid curves showing the characteristics of the pump he proposes to furnish. He must guarantee also the efficiency of his pump at 8,000,000 gallons capacity when working under the total head (previously explained). The pump shall be carefully tested before it leaves the manufacturer's shop to show that the efficiency guaranteed has been obtained. A certified test shall be submitted for the approval of the ....Water Board before shipment is made and notice 10 days previous to test shall be sent to the ....Water Board so that it may be present if it desires.

Should the efficiency of the pump as determined by the test fall below that guaranteed, the.......... Water Board may reject the pump or at its option may accept the pump at such reduction in the original contract price as the city of ....may suffer in monetary loss during a period of eight years through the lower efficiency.

The Contractor shall furnish the..............Water Board with the necessary facilities for carefully inspecting the apparatus during the process of manufacture.

FOUNDATION. The foundation for the unit will be erected by the city in accordance with drawings to be furnished by the contractor. The contractor is to supply all foundation bolts and plates. The Contractor is to furnish, erect and connect the unit complete up to the discharge flange of the pump; also to make necessary and suitable connections for the operation of the hydraulically or electrically controlled valve in the discharge pipe.

AUXILIARY APPARATUS. The Contractor is to furnish, erect, wire up and make all necessary connections to such auxiliary apparatus as may be required for the quick and successful operation of his unit.

WRENCHES. The Contractor is to furnish all special wrenches or tools required in assembling or in dismantling either the pump or the motor.

GAGES AND PANEL. The Contractor to provide a slate panel, dull black finish, matching the electrical board and mounted alongside same, containing the following: A seven day clock mounted in a brass gage case, black finish; a 10″ dial brass mounted suction gage and a 10″ dial brass mounted delivery gage,— these being connected to the suction and delivery pipes respectively. These gages to be marked in feet, pounds, or inches of mercury as may be requested by the..........Water Board, and the cases given a black finish.

PAINTING. The Contractor is to paint all machinery and piping erected by him. Such castings as are in sight from the floor of the pump room are to be made smooth, nicely fitted at all joints and flanges, filled with a proper paint filler and painted and striped in such colors as the Water Board may direct.

DEBRIS. The Contractor is to remove all blocking, tools or other material used by him in erecting and installing his work and to remove all debris of any nature in and around the pumping station, produced by him in carrying out this contract, at least 100 feet from station or to such place as he may be directed.

BIDS. Bids must be made in duplicate. Each bidder must leave with his bid a properly certified check for the sum of two thousand dollars ($2000) payable to the order of the City of ...., which check will be returned to the bidder unless forfeited as hereinafter provided.

BOND. A bond will be required for the faithful performance of the contract in the sum of 50% of the contract price with a surety company approved by the mayor.

The bidder is requested to name the surety company which will sign this bond in case the contract is awarded him.

If notice of the acceptance of the bid shall, within twenty days after June 20th, 1914, be given to the bidder by the.............Water Board, the bond must be furnished within ten days (Sunday excepted) after such notification; and in case of the failure of the bidder after such notification to furnish the bond within said time the bid may be considered as abandoned and the certified check accompanying the bid may be forfeited to the City.

Description. Each bidder is to furnish with his bid detailed description and specifications covering the apparatus he purposes to install.

Drawings. Each bidder is to furnish dimensioned drawings giving the general outside measurements of the entire apparatus when assembled together with such drawings or cuts as may be necessary to show the construction of his apparatus.

Weights. The individual weights of the rotor, stator and pump are to be given and photographs of typical equipment or design proposed should be furnished if possible.

Wiring. The bidder is to attach to his proposal wiring diagrams and detail drawings of the switchboard and power wiring.

Motor Performance. The bidder is to furnish guarantee as to motor performance when operating under the following conditions:

(1) Speed regulation when operating between no load and full load, stating load at which motor is rated.

(2) Power factor at 25, 50, 75, 100 and 125 per cent load.

(3) Momentary overload, per cent which motor will carry safely.

(4) Efficiency based on room temperature of 25° C. at the following percentages of load: (Respective ultimate temperatures used in the calculation of each case, to be stated).

25, 50, 75, 100 and 125 per cent load.

(5) Torque: Give pull out and starting torque in terms of full load torque.

(6) Temperature rise at 125 per cent normal rating for two hours following a run at normal rating of sufficient length to enable the motor to attain a constant temperature.

(7) Certified tests covering the preceding to be furnished by the party to whom the contract is awarded before the apparatus leaves the manufacturer's shop. Shipment not to be made until approved by the...........Water Board.

Test sheets are to be accompanied by a description of the method of test, which should as far as possible be in accordance with the Standardization Rules of the American Institute of Electrical Engineers. If doubt arises that the unit has not come up to test the.......... Water Board reserves the right to conduct another test after the installation; the party in error being responsible for payment of expenses of test.

Bearings. The bidder is to guarantee that all bearings will be continuously lubricated and will run continuously without overheating.

Repairs. The bidder is to agree to make all repairs which may be made necessary through original faulty construction, design or workmanship, for a period of one year after the unit goes into regular service, at his own expense.

Neither experimental nor unusual types of apparatus will be considered.

Units Previously Installed. Each bidder must be prepared to prove to the satisfaction of the..............Water Board that he has previously installed units of the type he proposes to furnish and he shall state where such units are in successful operation.

The bidder must state the general type, design and builder's name, of any part of the unit which is not built at the works of his own company.

Delivery. The bidder must give the date of delivery and the time required for the erection of the completed plant.

Payments. Payments will be made as follows: One-third of the contract price ten days after the delivery of the motor, pump and accessories; one-third within thirty days after satisfactory and successful operation; one-third thirty days after the acceptance of the unit by the city.

Acceptance. The.............Water Board reserves the right to reject any or all bids or to award the contract as it deems best.

The general design and accessibility of the parts, together with the cost will be considered in awarding this contract.

Bidder to Add to his Specifications. The bidder will submit his bid and his specifications on his own printed forms and will add to the same the following:

That he will indemnify and save harmless the city from all claims against the city, mechanics, laborers, and others for work performed or material furnished for carrying on the contract.

That he will indemnify and save harmless the city, its agents and employees, from all suits and claims against it or them or any of them, for damage to private corporations and individuals caused by the construction of the work to be done under this contract; or for the use of any invention, patent, or patent right, material, labor or implement by the contractor or from any act, omission or neglect by him, his agents, or employees, in carrying on the work; and that he agrees that so much of the money due to him under this contract as may be considered necessary by the..............Water Board may be retained by the city until all suits or claims for damages as aforesaid shall have been settled and evidence to that effect furnished to the..............Water Board.

The successful bidder will be required to furnish a certificate to the..............Water Board certifying that the men employed by him on the work herein set forth are insured under the provision of the Workmen's Compensation Act, so-called, of Massachusetts.

That he agrees to do such extra work as may be ordered in writing by the..........Water Board, and to receive in payment for same its reasonable cost as estimated by the ....Water Board plus fifteen per cent of said estimated cost.

That he agrees to make no claim for compensation for extra work unless the same is ordered in writing by the..............Water Board.

And that he still further agrees that the..............Water Board may make alterations in the work provided that if such changes increase the cost he shall be fairly remunerated and in case they diminish the cost, the proper reduction from the contract price shall be made, — the amount to be paid or deducted to be determined by the..............Water Board.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Coal Supply — 1914-1915

The Massachusetts Institute of Technology invites your bid on its supply of coal for the forthcoming fiscal year, July 1, 1914-July 1, 1915, on the following terms:

(1) Delivery

Daily, as called for, at 491 Boylston St., rear of 26 Trinity Place, Garrison St., and elsewhere, if desired, at the Technology buildings.

(2) Kinds and Amounts

(a) No. 2 Buckwheat, 2700 tons, more or less

(b) Semi-bituminous, 3800 tons, more or less

(3) Specifications

(a) No. 2 Buckwheat — free from dust.

(b) Semi-bituminous — of good steaming quality. The coal offered should be specified in terms of moisture *"as received,"* ash, volatile matter, sulphur and B. T. U., "dry coal" basis, which values become the standards for the coal of the successful bidder. The trade name of the coal should be given.

(4) Prices and Payments

(a) No. 2 Buckwheat — payments monthly at price named.

(b) Semi-bituminous — payments monthly on the basis of price named in bid, corrected for variations as to heat value, ash and moisture above or below, as follows:

Heat Value — On a "dry coal" basis, no adjustment in price will be made for variations of 1% or less in the number of B. T. U.'s from the guaranteed standard. When such variations exceed 1%, the adjustment will be proportional and determined as follows:

$$\frac{\text{B. T. U. delivered coal, "dry"}}{\text{B. T. U. specified in bid}} \times \text{Bid price} = \text{resulting price.}$$

Ash — On a "dry coal" basis, no adjustment in price will be made for variations of 1% or less above or below the per cent of ash guaranteed. When such variation exceeds 1%, the adjustment in price will be determined as follows:

The difference between the ash content of analysis and the ash content guaranteed will be divided by 2 and the quotient multiplied by bid price, the result to be added to or subsracted from the B. T. U. adjusted price or the bid price, if there is no B. T. U. adjustment, according to whether the ash content by analysis is below or above the percentage guaranteed.

Moisture — The price will be further adjusted for moisture content in excess of amount guaranteed, the deduction being determined by multiplying the price bid by the percentage of moisture in excess of the amount guaranteed.

(5) Sampling and Testing

The samples of coal shall be taken by the Institute or its representative and no other sample will be recognized. The coal dealer or his representative may witness the operation of the sampling if so desired. Samples of the coal delivered will be taken by the Institute or its representative from the wagons while being unloaded. Two or more shovelfuls of coal shall be taken from each wagon load and placed in a metal receptacle under lock. Not less than three times in any one month the samples, thus accumulated, shall be thoroughly mixed and quartered in the usual manner. The final sample is to be pulverized and passed through an 80-mesh sieve. A part of the final sample shall be put aside in an air-tight jar properly marked, for the coal dealer, so that he may verify results if he so desires.

The coal shall be dried for one hour in dry air at a temperature between 104° C. and 105° C.

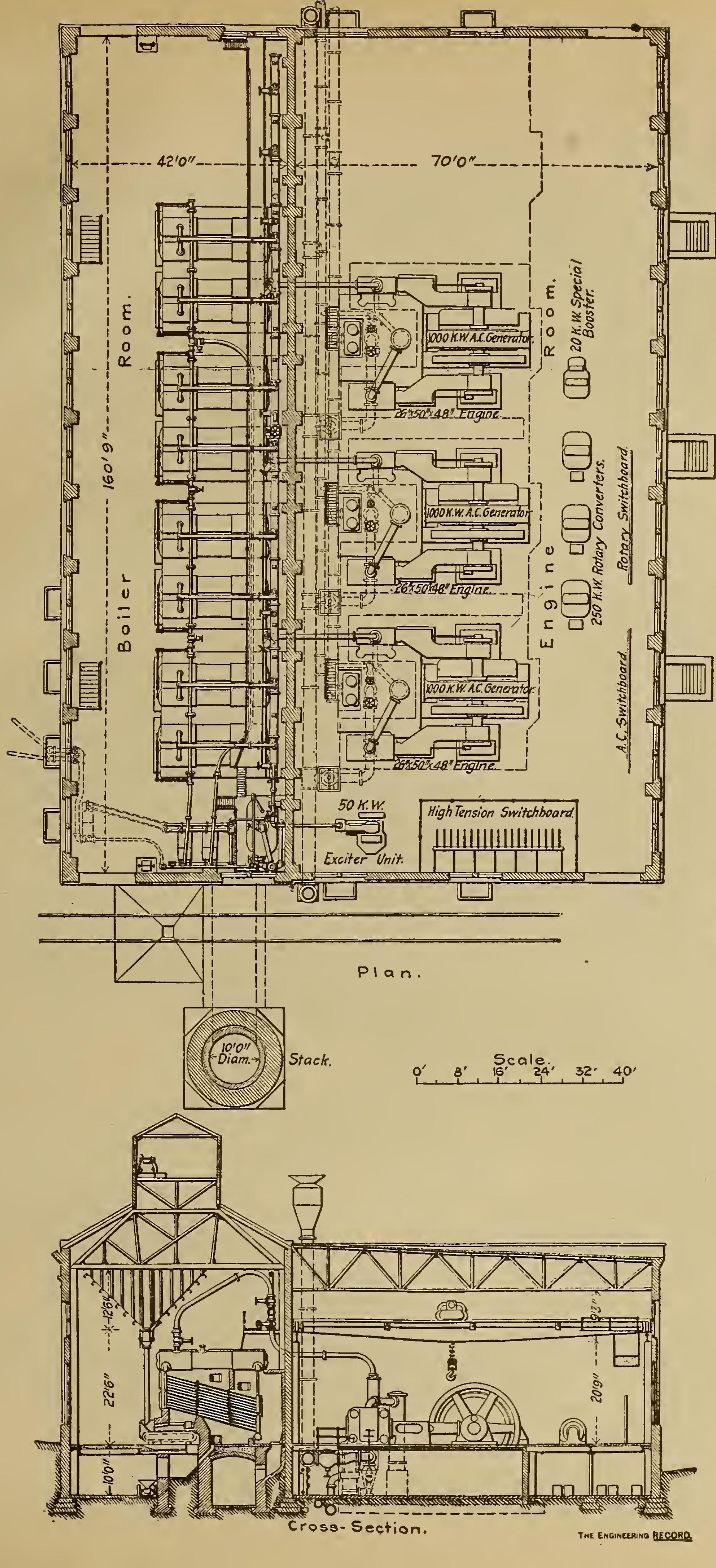
The coal shall be tested by the Institute, a bomb calorimeter being used. Should the coal dealer question the results, a sufficient quantity of the original sample is to be furnished him for testing if he so requests it.

The average of the results of the tests made each month shall be the basis for determining the price to be paid for coal delivered during that month.

(6) Limits

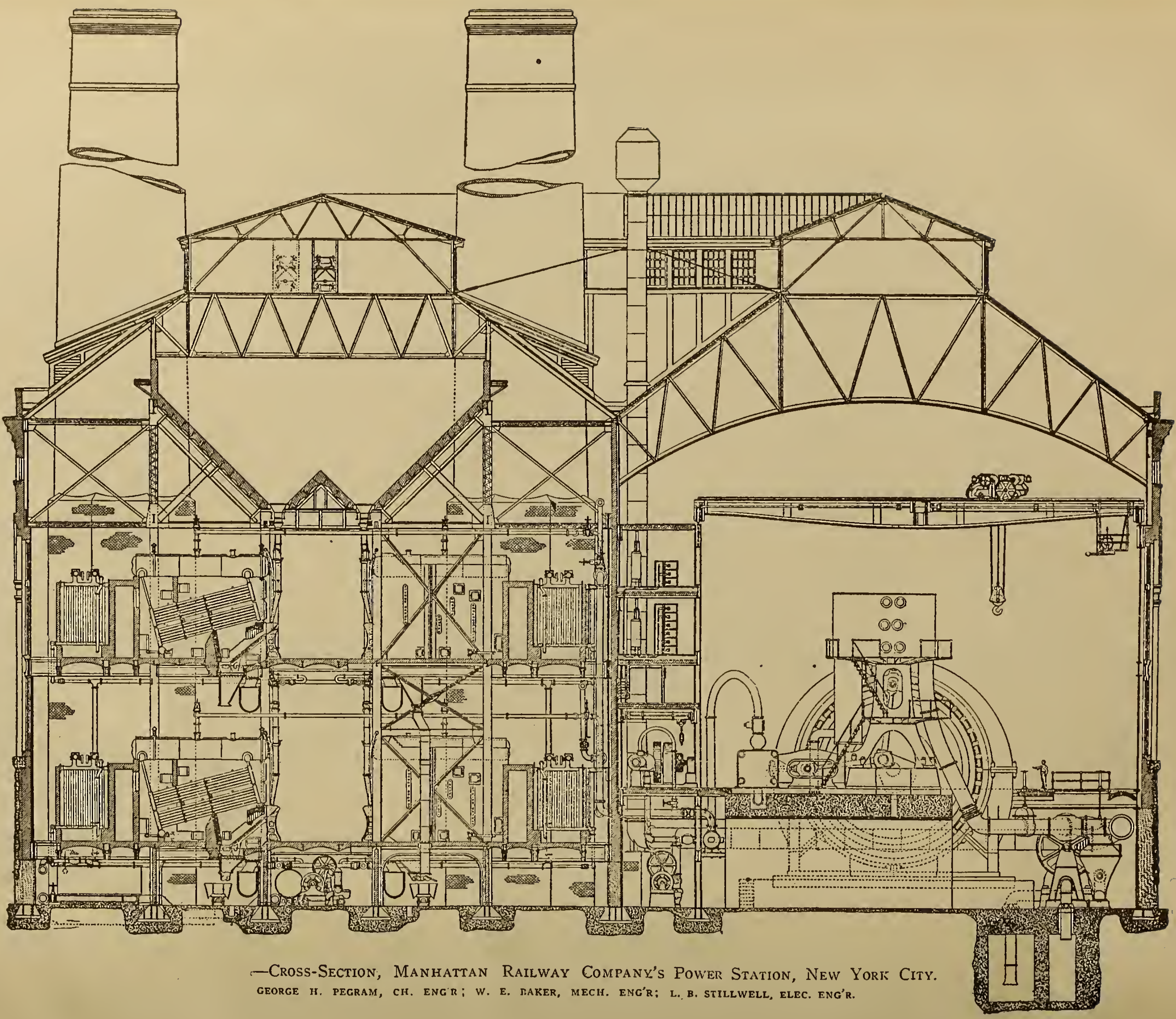
Should the heating value per pound of dry coal fall below 14,500 B. T. U., or should the moisture exceed 3%, or the ash exceed 7%, or the sulphur 1%, or the volatile matter 20%, the agreement may be terminated at the option of the Institute.

(7) The Right to reject any or all bids is reserved by the Institute.

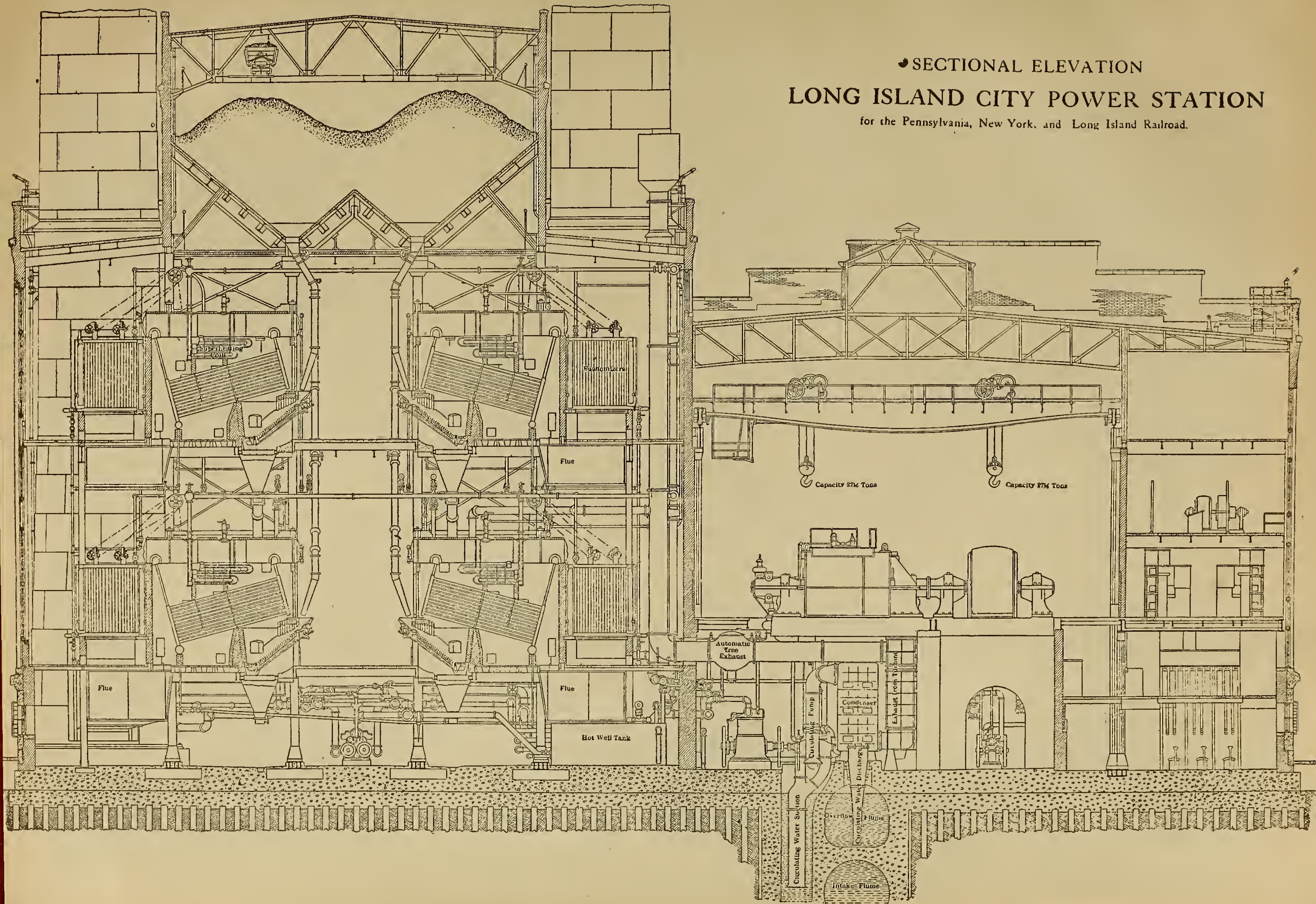


—Power Station Union Traction Company, Anderson, Ind.

Sargent & Lundy, Engineers.



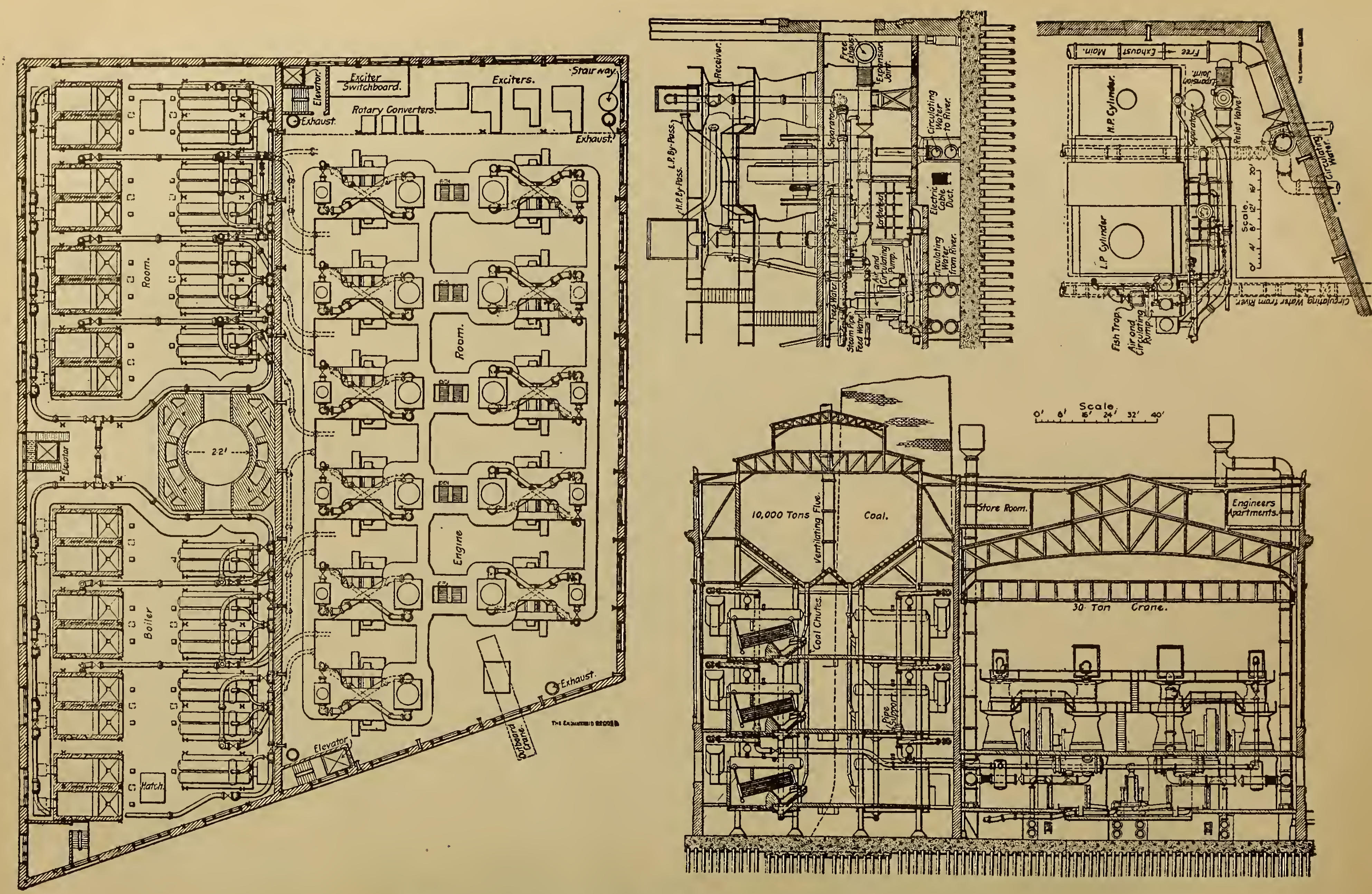
—Cross-Section, Manhattan Railway Company's Power Station, New York City.
George H. Pegram, Ch. Eng'r; W. E. Baker, Mech. Eng'r; L. B. Stillwell, Elec. Eng'r.



SECTIONAL ELEVATION

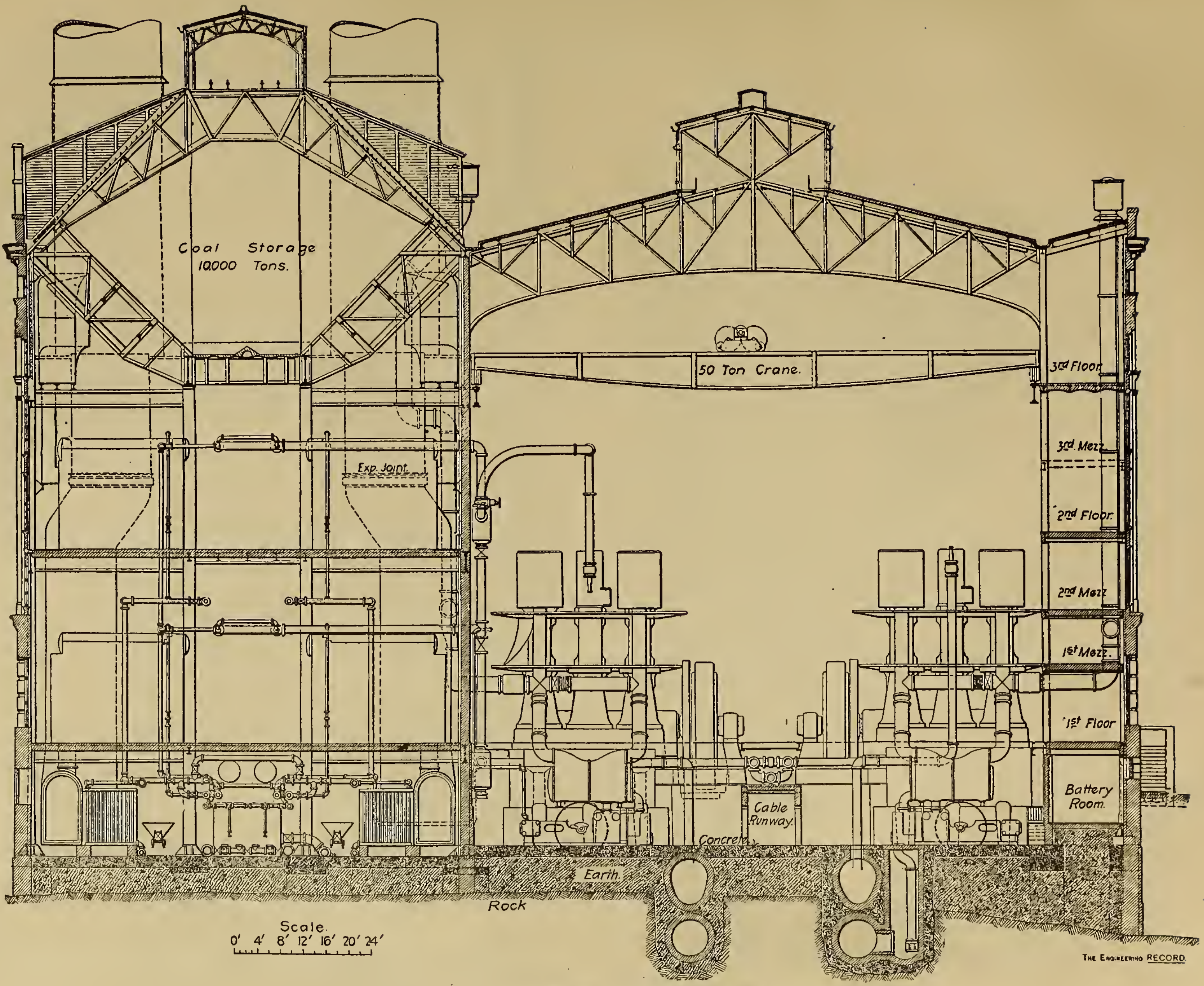
LONG ISLAND CITY POWER STATION

for the Pennsylvania, New York, and Long Island Railroad.

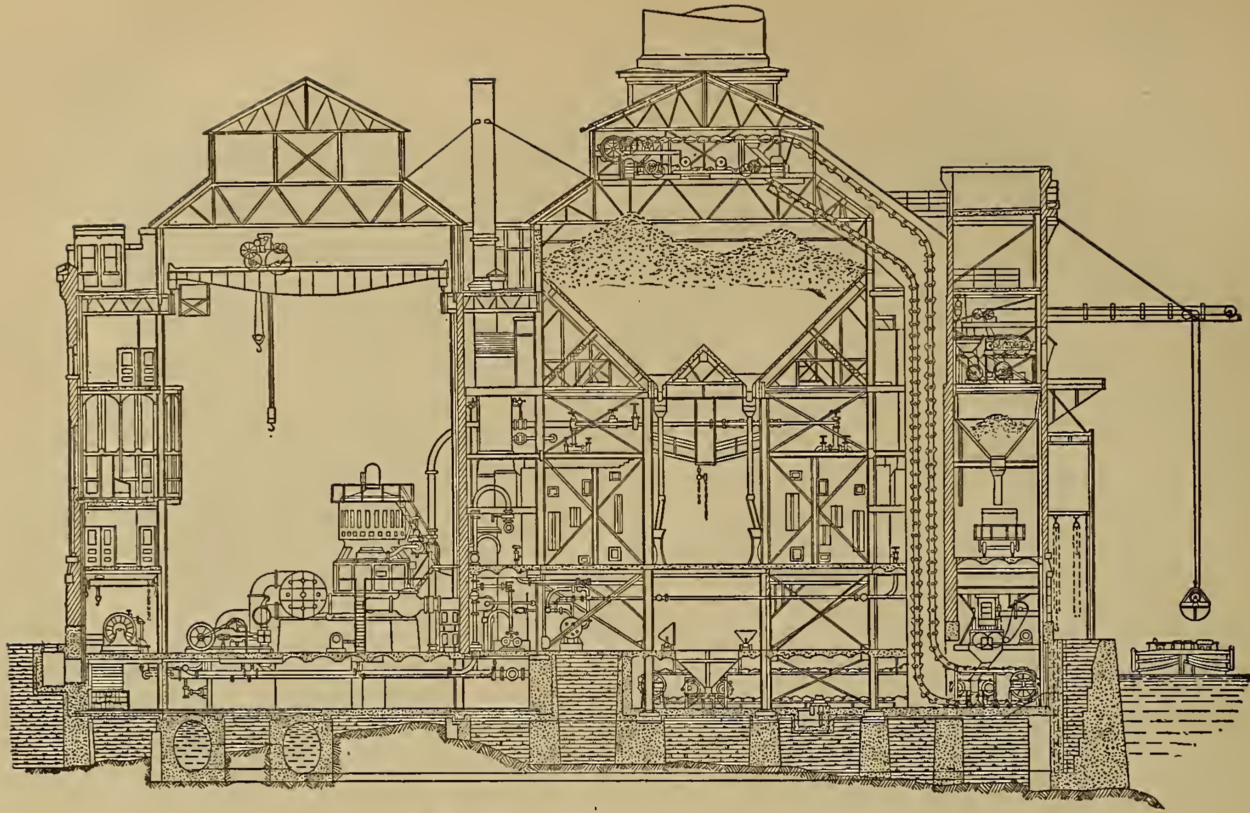


.—Ninety-Sixth Street Power Station, Metropolitan Street Railway Company, New York.

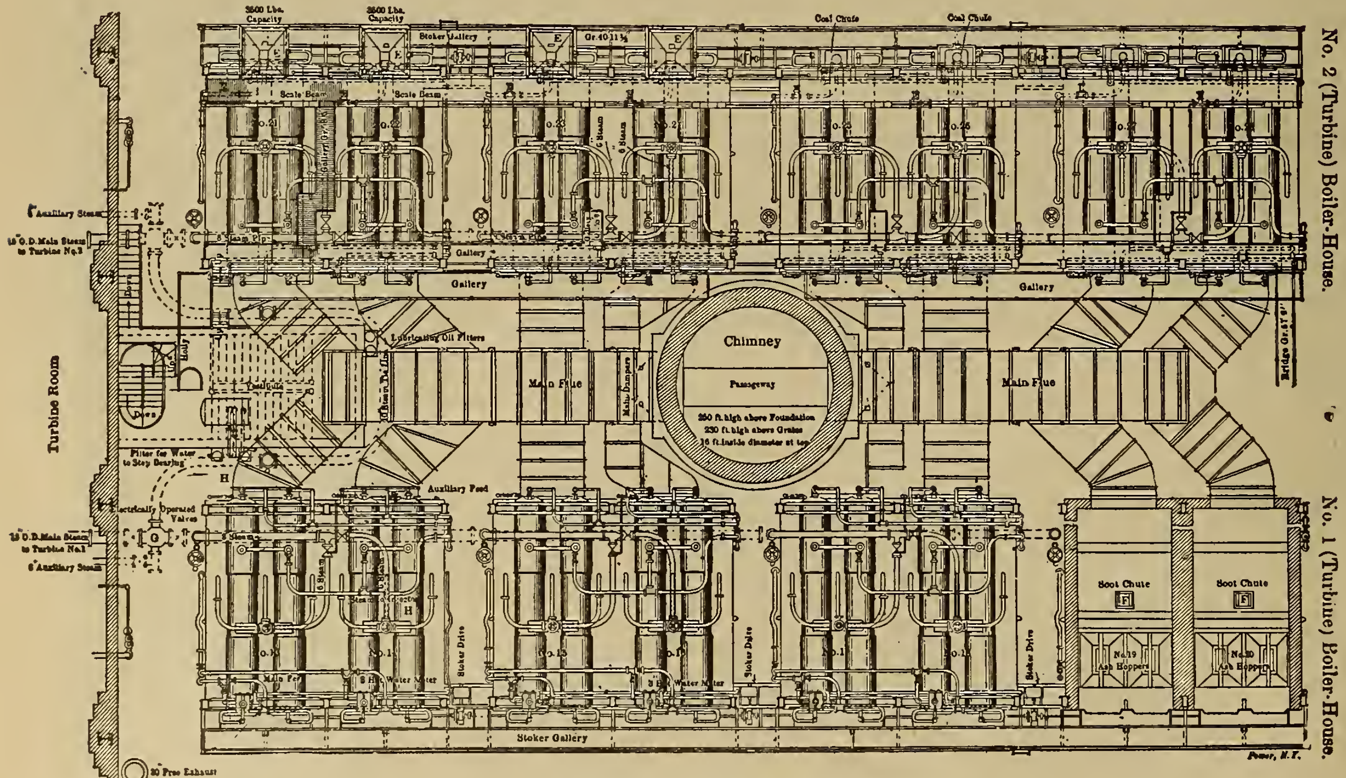
M. C. Starrett, Chief Engineer; F. S. Pierson, Consulting Engineer.



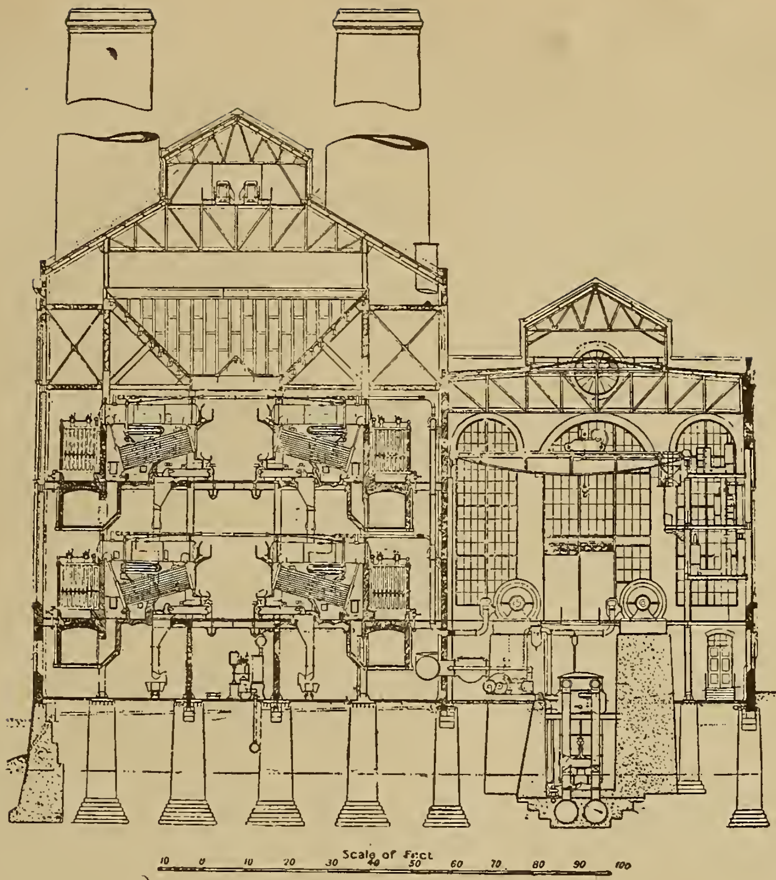
—Cross-Section Waterside Station, New York Edison Company.



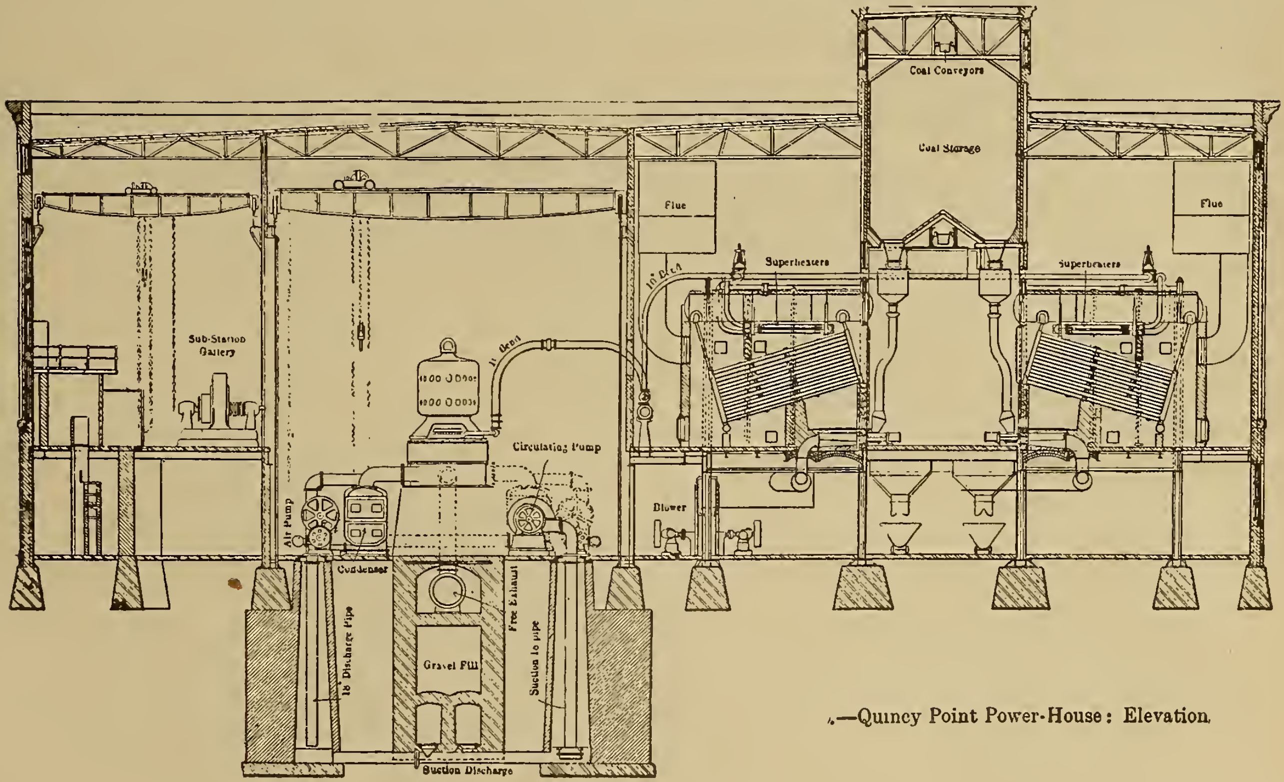
SECTIONAL ELEVATION OF PORT MORRIS STATION.



—Boston Edison L Street Power-House.



.—Lots Road, Chelsea: Sectional Elevation.



.—Quincy Point Power-House: Elevation.